AD NO. ___________________________
DTC PROJECT NO. 8-CO-160-UXO-021
REPORT NO. ATC 10540

STANDARDIZED

UXO TECHNOLOGY DEMONSTRATION SITE

SCORING RECORD NO. 928

SITE LOCATION:
ABERDEEN PROVING GROUND

DEMONSTRATOR:
U.S. GEOLOGICAL SURVEY
DENVER FEDERAL CENTER
BLDG. 20, MS-964
DENVER, CO 80225-0046

TECHNOLOGY TYPE/PLATFORM:
ALLTEM/TOWED

AREAS COVERED:
BLIND GRID
OPEN FIELD (DIRECT FIRE AREA)
OPEN FIELD (INDIRECT FIRE AREA)

PREPARED BY:
U.S. ARMY ABERDEEN TEST CENTER
ABERDEEN PROVING GROUND, MD 21005-5059

MARCH 2011

Prepared for:
SERDP/ESTCP
MUNITIONS MANAGEMENT
ARLINGTON, VA 22203

U.S. ARMY DEVELOPMENTAL TEST COMMAND
ABERDEEN PROVING GROUND, MD 21005-5055

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REPORT DOCUMENTATION PAGE					Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
March 2011	Final	2-5, 8-10 March 2010

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
STANDARDIZED UXO TECHNOLOGY DEMONSTRATION SITE SCORING RECORD NO. 928	
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
McClung, Stephen J.	8-CO-160-UXO-021
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
U.S. Army Aberdeen Test Center 400 Colleran Road Aberdeen Proving Ground, MD 21005-5059	ATC-10540

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
Program Manager SERDP/ESTCP Munitions Management Arlington, VA 22203	
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) Same as Item 8

12. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution unlimited.

13. SUPPLEMENTARY NOTES

None

14. ABSTRACT

This scoring record documents the efforts of USGS to detect and discriminate inert unexploded ordnance (UXO) utilizing the APG Standardized UXO Technology Demonstration Site open field. This scoring record was coordinated by J. Stephen McClung and the Standardized UXO Technology Demonstration Site Scoring Committee. Organizations on the committee include the U.S. Army Corps of Engineers, the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, the Institute for Defense Analysis, the U.S. Army Environmental Command, and the U.S. Army Aberdeen Test Center.

15. SUBJECT TERMS

Environmental Security Technology Certification Program, APG, Standardized UXO Technology Demonstration Site, blind grid, open field, indirect fire, pushcart.

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(Include area code)*
Unclassified	Unclassified	Unclassified	SAR		

ACKNOWLEDGMENTS

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SECTION 1. GENERAL INFORMATION

1.1 BACKGROUND

Technologies under development for the detection and discrimination of unexploded ordnance (UXO) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at Aberdeen Proving Ground (APG), Maryland, and U.S. Army Yuma Proving Ground (YPG), Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the Government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments (app E, ref 1).

The Standardized UXO Technology Demonstration Site Program is a multiagency program spearheaded and funded by the Environmental Securities Technology Certification Program (ESTCP), the Strategic Environmental Research and Development Program (SERDP). The U.S. Army Aberdeen Test Center (ATC) provides programmatic and field support for technology demonstration and evaluation, and maintains a repository of inert munition items available to the UXO community. The U.S. Army Environmental Command maintains the Standardized UXO Technology Demonstration Site Program web page (http://aec.army.mil/usaec/technology/uxo01.html), which contains program information, vendor demonstration instructions and copies of all published vendor demonstration scoring records.

1.2 SCORING OBJECTIVES

The objective in the Standardized UXO Technology Demonstration Site Program is to evaluate the detection and discrimination capabilities of a given technology under various field and soil conditions. Inert munitions and clutter items are positioned in various orientations and depths in the ground.

The evaluation objectives are as follows:

a. To determine detection and discrimination effectiveness under realistic scenarios with various targets, geology, clutter, density, topography, and vegetation.

b. To determine cost, time, and workforce requirements to operate the technology.

c. To determine the demonstrator’s ability to analyze survey data in a timely manner and provide prioritized Target Lists with associated confidence levels.

d. To provide independent site management to enable the collection of high quality, ground-truth (GT), geo-referenced data for post-demonstration analysis.

1.2.1 Scoring Methodology

a. The scoring of the demonstrator's performance is conducted in two stages: response stage and discrimination stage. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver-operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of clutter detection (P_{cd}) or the probability of false positive (P_{fp}). Those that do not correspond to any known item are termed background alarms. The background alarms are addressed as either probability of background alarm (P_{ba}) or background alarm rate (BAR).

b. The response stage scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate munitions from other anomaly sources. For the blind grid response stage, the demonstrator provides a target response from each and every grid square along with a threshold below which target responses are deemed insufficient to warrant further investigation. This list is generated with minimal processing and, since a value is provided for every grid square, includes amplitudes both above and below the system noise level. For the open field, the demonstrator provides a list of all anomalies deemed to exceed a demonstrator selected target detection threshold. An item (either munition or clutter) is counted as detected if a demonstrator indicates an anomaly within a specified distance (Halo Radius (R_{halo})) of a ground truth item.

c. The discrimination stage evaluates the demonstrator's ability to correctly identify munitions as such and to reject clutter. For the blind grid discrimination stage, the demonstrator provides the output of the discrimination stage processing for each grid square. For the open field, the demonstrator provides the output of the discrimination stage processing for anomaly reported in the response stage. The values in these lists are prioritized based on the demonstrator's determination that a location is likely to contain munitions. Thus, higher output values are indicative of higher confidence that a munitions item is present at the specified location. For digital signal processing, priority ranking is based on algorithm output. For other discrimination approaches, priority ranking may be based on rule sets or human judgment. The demonstrator also specifies the threshold in the prioritized ranking that provides optimum performance, (i.e., that is expected to retain all detected munitions and reject the maximum amount of clutter).

d. The demonstrator is also scored on efficiency and rejection ratios, which measure the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of munitions detections from the anomaly list, while rejecting the maximum number of anomalies arising from nonmunitions items. Efficiency measures the fraction of detected munitions retained after discrimination, while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the maximum number of munitions detectable by the sensor and its accompanying clutter detection/false positive rate or BAR.

e. Based on configuration of the GT at the standardized sites and the defined scoring methodology, in some cases, there exists the possibility of having anomalies within overlapping halos and/or multiple anomalies within halos. In these cases, the following scoring logic is implemented:

(1) In situations where multiple anomalies exist within a single R_{halo}, the anomaly with the strongest response or highest ranking will be assigned to that particular GT item. If the responses or rankings are equal, then the anomaly closest to the GT item will be assigned to the GT item. Remaining anomalies are retained and scored until all matching is complete.

(2) Anomalies located within any R_{halo} that do not get associated with a particular GT item are excess alarms and will be disregarded.

f. In some cases, groups of closely spaced munitions have overlapping halos. The following scoring logic is implemented (App A, fig. A-1 through A-9):

(1) Overall site scores (i.e., P_d) will consider only isolated munitions and clutter items.

(2) GT items that have overlapping halos (both munitions and clutter) will form a group and groups may form chains.

(3) Groups will have a complex halos composed of the composite halos of all its GT items.

(4) Groups will have three scoring factors: groups found, groups identified, and group coverage. Scores will be based on 1:1 matches of anomalies and GT.

(a) Groups Found (Found): the number of groups that have one or more GT items matched divided by the total number of groups. Demonstrators will be credited with detecting a group if any item within the group is matched to an anomaly in their lists.

(b) Groups Identified (ID): the number of groups that have two or more GT items matched divided by the total number of groups. Demonstrators will be credited with identifying that a group is present if multiple items within the composite halo are matched to anomalies in their lists.

(c) Group Coverage (Coverage): the number of GT items matched within groups divided by the total number of GT items within groups. This metric measures the demonstrator accuracy in determining the number of anomalies within a group. If five items are present and only two anomalies are matched, the demonstrator will score 0.4. If all five are matched, the demonstrator will score 1.0.

(5) Location error will not be reported for groups.

(6) Demonstrators will not be asked to call out groups in their scoring submissions. If multiple anomalies are indicated in a small area, the demonstrator will report all individual anomalies.

(7) Excess alarms within a halo will be disregarded.

g. All scoring factors are generated utilizing the Standardized UXO Probability and Plot Program, version 4.

1.2.2 Scoring Factors

Factors to be measured and evaluated as part of this demonstration include:

a. Response stage ROC curves:

(1) Probability of detection (P_d^{res}).

(2) Probability of clutter detection (P_{cd}).

(3) Background alarm rate (BAR^{res}) or probability of background alarm (P_{ba}^{res}).

b. Discrimination stage ROC curves:

(1) Probability of detection (P_d^{disc}).

(2) Probability of false positive (P_{fp}).

(3) Background alarm rate (BAR^{disc}) or probability of background alarm (P_{ba}^{disc}).

c. Metrics:

(1) Efficiency (E).

(2) False positive rejection rate (R_{fp}).

(3) Background alarm rejection rate (R_{ba}).

d. Other:

(1) Probability of detection by size, depth, and density.

(2) Classification by type (i.e., 20-, 40-, 105-mm, etc.).

(3) Location accuracy for single munitions.

(4) Equipment setup, calibration time, and corresponding worker-hour requirements.

(5) Survey time and corresponding worker-hour requirements.

(6) Reacquisition/resurvey time and worker-hour requirements (if any).

(7) Downtime due to system malfunctions and maintenance requirements.

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 Demonstrator Point of Contact (POC) and Address

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2.1.2 System Description (provided by demonstrator)

The ALLTEM is an ‘on-time’ time-domain electromagnetic induction system that consists of exciting and detecting 3-component fields using multiple Tx and Rx coils. The triangle current excitation waveform (pulse rate 90Hz) provides immediate visual separation between ferrous and non-ferrous metal objects. The ALLTEM records data to late times which helps suppress the geologic response relative to the UXO response. The system is pulled by a small Kubota tractor with a small 2 kW generator at the front (see photo below). The ALLTEM sensor is a 1-meter cube that sits in a cart and has a minimum height above the ground of about 6 inches that can be raised up an additional 6 inches to traverse over surface obstacles. Two LEICA GPS1200 RTK rover systems provide the sensor location and tractor position into a USGS-developed survey navigation program. Survey traverses will have 0.5 meter separation with a data density of approximately 15 to 20 cm (traveling at a nominal speed of 1.0 m/sec with a sampling cycle rate for each Tx coil of approximately 300 ms).

Figure 1. Demonstrator's system, EM61 MKII/towed array.

2.1.3 Data Processing Description (provided by demonstrator)

Target selection criteria: This section will detail the target selection criteria and the data required to implement the criteria by answering the following questions:

a. *What kind of pre-processing (if any) is applied to the raw data (e.g., filtering, etc.)?* ALLTEM preprocessing is a batch process of all binary waveform survey data via a LABVIEW program that performs background subtraction, low-pass and band-width filtering, determination of ferrous/nonferrous/mixed composition, and then exports an ASCII file containing data at 16 time gates along the waveform.

b. *What is the format of the data both pre and post processing of the raw data (e.g., ASCII, binary, etc.)?* The original LABVIEW acquisition data consists of binary waveform files with ASCII headers. There is one file per configuration. These are converted in the LABVIEW preprocessing program to an ASCII format that is carried throughout the rest of the processing and analysis.

c. *What algorithm is used for detection (e.g., peaks of signal surpassing threshold, etc.)?* In 2008 we have migrated all our processing and analysis software to work within the Geosoft Oasis Montaj platform. Once the data is imported into Oasis, an area that is deemed to be target free is designated. This area forms the threshold basis on which a statistical analysis is performed using the "R Project for Statistical Computing" (http://www.r-project.org) statistics package, version 2.10.1. Wilkes-Shapiro and T-tests characterize the acquired data and then Blakely peakedness tests are performed to designate the locations of the potential targets. This is all done automatically for all 19 ALLTEM receiver configurations.

d. *Why is this algorithm used and not others?* We use the calculated statistics for both picking out targets and as part of the classification analysis at the end of the process.

e. *On what principles is the algorithm based (e.g., statistical models, heuristic rules, etc.)?* As just mentioned, the algorithm is based on a statistical analysis of the acquired data.

f. *What tunable parameters (if any) are used in the detection process (e.g., threshold on signal amplitude, window length, filter coefficients, etc.)?* Tunable parameters include the background threshold level, the number of standard deviations away from the target threshold used to determine signal levels, the search radius around each selected target (used for merging multiple targets at same location from different receiver polarizations), the areas of what are considered to be statistically 'significant' data for a particular target, and analytic signal calculations for certain receiver polarizations.

g. *What are the final values of all tunable parameters for the detection algorithm?* The final values for the tunable parameters will be determined by the data in the field. The background threshold values will be determined independently for each area surveyed. The search radius will be determined by the largest target detected in each survey area.

Parameter estimation: This section should include the details of which parameters will be extracted from the sensor data for each detected item for characterization. Please answer the following questions:

a. *Which characteristics will be extracted from each detected item and input to the discrimination algorithm (e.g., depth, size, polarizability coefficients, fit quality, etc.)?* Characteristics extracted for each detected item include inferred composition (ferrous/nonferrous/mixed), horizontal location and depth, azimuth, inclination, magnetic polarizability coefficients, and the ratio of polarizability coefficients.

b. *Why have these characteristics been chosen and not others (e.g., empirical evidence of their ability to help discriminate, inclusion in a theoretical tradition, etc.)?* We have determined empirically from previous surveys and by models that these characteristics (composition, polarizabilities, ratios of polarizabilities) have proven effective at discriminating UXO versus clutter versus blank holes.

c. How are these characteristics estimated (e.g., least-mean-squares fit to a dipole model, etc.), include the equations that are used for parameter estimation?

The ALLTEM response is modeled using a conductive, magnetic, and optionally, a viscous magnetic earth. The integral expressions for the magnetic fields generated by infinitely small vertical magnetic dipoles (VMDs) and horizontal magnetic dipoles (HMDs) over a conductive magnetic half space are given by Ward and Hohmann (1988). These integrals are numerically evaluated using Anderson's (1979) fast Hankel transform to produce Green's functions for the magnetic field due to a dipole over a half-space. The ground response at a given receiver coil due to excitation by a given transmitter coil is calculated by numerically evaluating the following integrals.

$$V_{rx}(\omega) = -i\omega T(\omega) \int_{RXloop} \hat{n}_{rx} \cdot \int_{TXloop} \hat{n}_{tx} \cdot \vec{\vec{G}}^{-}(\sigma, \mu, \vec{r}, \vec{r}')d\vec{r}d\vec{r}' \tag{1}$$

where *T(ω)* is the Fourier transform of the transmitter excitation (a triangle wave), $\vec{\vec{G}}^{-}(\sigma, \mu, \vec{r}, \vec{r}')$ is the dyadic Green's function for the fields above the surface due to a dipole moment above the surface, σ is the ground conductivity, μ is magnetic permittivity (possibly complex and frequency dependent), ω is radian frequency, V_{rx} is the voltage at the receiver coil, $\hat{n}_{tx}$ and $\hat{n}_{rx}$ are the normals to the planes containing the transmitting and receiving coils, and the integrals are over the area of the transmitting and receiving coils. This procedure is used to calculate the voltage at each receiving coil in the gradiometer, and the simulated result is the difference between these coil voltages. Finally, the frequency-domain coil voltage is converted into a time-domain signal using a numerical Fourier transform (FFT).

Modeling the response of a conductive permeable spheroid is slightly more involved. First, the magnetic field below the surface is calculated at the center of the target using (2). Here the dyadic Green's function is now for the fields below the surface due to a dipole moment above the surface.

$$\vec{H}_0(r, \omega) = T(\omega) \int_{TXloop} \hat{n}_{tx} \cdot \vec{\vec{G}}^{+}(\sigma, \mu, \vec{r}, \vec{r}')d\vec{r}' \tag{2}$$

Next, the equivalent induced dipole moment $\vec{m}(t)$ for the target is calculated,

$$\vec{m}(\omega) = \vec{\vec{R}}^{T} \cdot \vec{\vec{M}}(\omega) \cdot \vec{\vec{R}} \cdot \vec{H}_0(r, \omega) \tag{3}$$

where $\vec{\vec{M}}(\omega)$ is the diagonal frequency-dependent magnetic-polarizability tensor. Calculations for specifying this tensor for conductive permeable prolate and oblate spheroids are given in Smith and Morrison (2006). $\vec{\vec{R}}$ is a rotation matrix that converts the magnetic field to target spheroid centric coordinates. Note that for a given incident field, only a single component of the polarizability tensor is excited. A fully polarimetric instrument switches through different coil configurations resulting in incident fields with components in all possible directions. The result is that all components of the polarizability tensor are excited, which provides more information about the target.

The final step is to calculate the fields at the receiver coils due to the induced dipole moments at the target. Using the reciprocity theorem, we find that the voltage induced in the receiver coil V_{rx} due to the induced target dipole moment $\vec{m}$ is related to magnetic field $\vec{H}_{uxo}$ at the target due to a current in the receiver coil I_{rx}.

$$V_{rx}(\omega) = -i\omega \frac{\mu \vec{H}_{uxo} \cdot \vec{m}(\omega)}{I_{rx}} \tag{4}$$

Equation 2 is used to calculate the magnetic field at the target, only now the integral is over the area of the receiver coil. As before, this procedure is used to calculate the voltage at each receiving coil in the gradiometer, and the simulated result is the difference between these coil voltages. Finally the frequency-domain coil voltage is converted into a time-domain signal using a numerical Fourier transform (FFT).

Using Equations 1-4 and Smith and Morrison's (2006) spheroid response, the ALLTEM response to the earth and the target are modeled separately, and then summed for the total response. Interactions between the target and surrounding medium are neglected (i.e., Born approximation). The magneto-static response due to magnetization of a permeable target is manifest as a square wave response, with the decaying electro-dynamic response due to induced eddy currents superimposed. The square wave magneto-static response is absent for the non-permeable target. Note also that the electro-dynamic eddy current decay lasts longer for the permeable target.

When processing large amounts of data, it is desirable to have a fast inversion algorithm, which in turn requires a fast forward model. Calculating the Green's function in equations 1 and 4 is computationally expensive, and is not needed is most cases (i.e., when viscous magnetic soil is not present). A faster approach to calculating the magnetic fields is to use the static Biot-Savart Law for free space. This works especially well for the ALLTEM system since all coils have a square shape. The magnetic field at $\vec{r}$ is the sum of the fields produced by the four straight wire segments, each with current $\vec{I}_n$, length 2*L*, and centered at $\vec{r}_n'$ (the midpoint of the wire segment):

$$\vec{H}(\vec{r}) = \sum_{n=1}^{4} \frac{\vec{I}_n \times \hat{R}_n}{4\pi} \left[\frac{|\vec{P}_n|}{d_2(d_2 + L - |\vec{Z}_n|)} - \frac{|\vec{P}_n|}{d_1(d_1 + L - |\vec{Z}_n|)} \right], \qquad (7)$$

$$d_1 = \sqrt{L^2 + 2L|\vec{Z}_n| + |\vec{P}_n|^2 + |\vec{Z}_n|^2}\ , \quad d_2 = \sqrt{L^2 - 2L|\vec{Z}_n| + |\vec{P}_n|^2 + |\vec{Z}_n|^2}\ , \qquad (8\text{-}9)$$

$$\vec{R}_n = \vec{r} - \vec{r}_n' , \qquad \vec{Z}_n = \vec{R}_n \cdot \hat{I}_n , \qquad \vec{P}_n = \vec{R}_n - \vec{Z}_n . \qquad (10\text{-}12)$$

Smith et al. (2004) presented a simple parametric form for estimating the time-domain *B* field response of a conductive permeable sphere due to a step function excitation. This is also the electro-dynamic ALLTEM response since its excitation is integral of the step (triangle wave), it uses *dB*/*dt* receivers, and the integral and derivative operations cancel each other. The form is a good approximation to the early-time, intermediate-time, and late-time portions of the response. The simple models for permeable and non-permeable spheres reduce to:

$$M_{sphere}(t,R) = \frac{4\pi R^3}{3}\frac{9\mu_r}{2(\mu_r+2)}\left(1+\sqrt{\frac{t}{\alpha}}\right)^{-\beta} e^{-t/\gamma}, \qquad (13)$$

$$\alpha = 1.38\tau_1, \quad \beta = \frac{2\sqrt{\alpha}(\mu_r+2)}{R\sqrt{\pi\sigma\mu_r\mu_0}}, \quad \gamma = \frac{\tau_0+\sqrt{\alpha\tau_0/2}}{1+\sqrt{\alpha/2\tau_0}-\beta/4}, \qquad (14\text{-}16)$$

$$\tau_0 = \sigma\mu_r\mu_0 R^2/\delta_1^2, \quad \delta_1 = \pi + \arctan\left((\delta_1\mu_r-\delta_1)/(\mu_r-1+\delta_1^2)\right), \qquad (17\text{-}18)$$

$$\tau_1^{\mu_r\approx 1} = \tau_0, \quad \tau_1^{\mu_r>>1} = \sigma\mu_r\mu_0 R^2/\left((\mu_r+2)(\mu_r-1)\right). \qquad (19\text{-}20)$$

We combined this form with Smith and Morrison's (2006) approximation of the polarizability tensor for a prolate spheroid in terms of that of a sphere. For the n^{th} element along the diagonal, this yields.

$$M_n(t) = \frac{2a^2b}{9R_n^3}\frac{\mu_r+2}{\mu_r}\left[\frac{1}{1-A_n}+\frac{\mu_r-1}{1+A_n(\mu_r-1)}\right]M_{sphere}(t,R_n). \qquad (21)$$

$$R_1 = b \qquad R_2 = a \qquad (22\text{-}23)$$

where *b* is the half-length of the spheroid, *a* is the radius, and the demagnetization factors A_n are given in Smith and Morrison (2006, eqns. A-2 and A-3). The magneto-static response is simply

$$M_n^{DC} = \left[\frac{\mu_r-1}{1+A_n(\mu_r-1)}\right]. \qquad (24)$$

Combining both the electro-dynamic and the magneto-static responses, we obtain

$$M_n^{ALLTEM}(t) = 2M_n(t) - M_n(t=5.55\cdot 10^{-3}) - M_n^{DC}, \qquad (25)$$

where the electro-dynamic response at 5.55 ms is subtracted to account for any eddy currents that have not decayed when the transmitted waveform changes slope. Finally, the time domain ALLTEM response is calculated from Equations 3, 4, and 25 where ω is replaced by *t*.

The inversion employs an iterative Gauss-Newton minimization combined with step-size optimization as follows,

$$\alpha\, \vec{J}^{\dagger}(\vec{x}_i)\cdot \vec{\vec{C}}^{-1}\cdot\left(\vec{f}(\vec{x}_i)-\vec{f}_0\right)=\vec{x}_{i+1}-\vec{x}_i\,, \tag{26}$$

$$\vec{J}(\vec{x}_i)=\nabla\vec{f}(\vec{x}_i)\,, \tag{27}$$

$$\vec{\vec{C}}=\begin{bmatrix}\sigma_1 & \dots & 0\\ \vdots & \ddots & \vdots\\ 0 & \cdots & \sigma_n\end{bmatrix}, \tag{28}$$

$$\min_{\alpha\in(0-1]}\left\|\vec{f}(\vec{x}_{i+1})-\vec{f}_0\right\|^2, \tag{29}$$

where $\vec{J}^{\dagger}(\vec{x}_i)$ is the pseudo-inverse of $\vec{J}(\vec{x}_i)$, and $\vec{f}(\vec{x})$ is the forward model vector containing predicted data samples, $\vec{f}_0$ is the measured data, $\vec{\vec{C}}$ is a diagonal matrix containing the data standard deviations (it is assumed that the data are identically distributed and statistically independent), and $\vec{x}$ contains the parameters. At each iteration, the step length is scaled by α which is varied in discrete steps over the interval (0,1] to find the step that results in the smallest least squares data misfit. Since the number of data (number of coil combinations times number of instrument locations times number of waveform points) far exceeds the number of parameters to be estimated, the pseudo-inverse of the Jacobian matrix is calculated by singular value decomposition. Instabilities due to poor conditioning are avoided by scaling the parameters so their ranges all lie within 1-2 orders of magnitude, and by only using singular values that have magnitudes of at least 10^{-3} times the dominant singular value. At each iteration, the target's orientation angles are constrained to be between $-\pi$ and π, and the spheroid diameters are constrained to be positive. Iteration stops when a local minimum is found, or the maximum allowable number of iterations is reached. This basic search algorithm is used with a state machine to estimate the target parameters as described below.

The first step in the parameter estimation problem is to choose an initial model. The *x* and y target locations are selected from the centroid of the anomaly, and the *z* location is estimated by finding the least squares minimum of

$$f_{depth}(z)=\sum_c\sum_n\left\|\ln\left[\left|\frac{\left|f^c(\rho_n,z)\right|-\left|f^c(0,z)\right|}{\left|f_0^c(\rho_n,z)\right|-\left|f_0^c(0,z)\right|}\right|\right]\right\|^2, \tag{30}$$

where f^c is the modeled data and f_0^c is the measured data for coil combination *c* at instrument location *n*. All data are from the same time-gate (usually t = 5 ms), and ρ_n is the horizontal distance from the centroid at instrument location *n*. This functional calculates the slopes of the logarithm of the fields versus distance from the target (i.e., slope is -3 for the fields of a static dipole decaying at r^{-3}), and compares the slopes of measured data and data modeled for a

spheroid. To determine a representative permeability value, the late-time magnitudes are examined to determine if the target is ferrous or non-ferrous ($\mu_r = 1$). For ferrous targets, the demagnetization effect must be considered (see fig. 5). For targets with relative permeabilities ranging from 50 to 1000, a nominal value of 100 is sufficient to model objects with aspect ratios less than about four, therefore the selected representative value of μ_r is held fixed during the inversion. An initial conductivity is chosen based values of typical metals used in UXO construction. The conductivity of aluminum alloys typically range from about $1.5{\cdot}10^7$ to $3.5{\cdot}10^7$ S/m, and steel alloys typically range from $0.2{\cdot}10^7$ to $0.9{\cdot}10^7$ S/m, which makes $1.0{\cdot}10^7$ S/m a reasonable starting value. Initial orientation angles (pitch and yaw) are zero.

With a representative permeability value, it is possible to determine the principle spheroid diameters using the response at time $t = 0^+$ (the instant the transmitter turns off). This however, requires a system with instantaneous turn off time and a receiver with infinite bandwidth. With some high-bandwidth systems, it may be possible to extrapolate back from earliest available time sample at a slope of $t^{1/2}$ to estimate the dimensions of the target.

In conducting trials with the minimization algorithm, it was observed that there is a basin of attraction associated with both prolate models and oblate models. Oftentimes, the evolving data misfit function would enter an incorrect basin of attraction only to find a local minimum. The solution to this problem is to minimize the misfit function using a prolate model, then using an oblate model, and then choose the solution with the best fit. While minimizing these functions, only data from a single time-gate (typically at $t = 5$ ms) are used, and both initial models use a larger diameter of 0.26 meter, and a smaller diameter of 0.1 meter. Because most of the energy in the ALLTEM waveforms from ferrous targets at times greater than 1 ms is magneto-static, the μ and σ are held fixed to reduce the degrees of freedom while searching for optimum prolate and oblate models. The final step is to polish the conductivity value using the best solution found thus far, using data from all time-gates selected for analysis and holding all other parameters fixed.

The mean squared error in the best-fit modeled data is assumed to be due to variations from a non-ideal systematic response. These variations include components of the instrument response not accounted for by the model (drift, non-linear response, etc.), components of target response not accounted for by the model, ambient EM noise, geologic noise, errors in instrument location, and attitude variations of the instrument. To estimate the uncertainty in the estimated parameters, each parameter is perturbed from its best-fit value until the mean squared error of the modeled data increases by the variance estimate of the data.

The number of data points is typically chosen to be less than ~1000 so that the inversion can be accomplished in a reasonable time frame (about a minute). When selecting a set of coil combinations to use in the analysis, the set that carries the most (orthogonal) information is desirable. To select a subset of coil combinations from the recorded set of 19 coil combinations, selections are made in order of decreasing data variance until a single selection for each of the nine possible polarization combinations (i.e., (Tx_x, Rx_x), (Tx_x, Rx_y), etc.) has been made. If more coil combinations are needed to fill the subset, then additional selections are made in order of decreasing data variance.

d. What tunable parameters (if any) are used in the characterization process? (e.g., thresholds on background noise, etc.)? Tunable parameters include all the parameters derived by the inversion process.

Classification: This section should include the details describing the algorithm and associated data and parameters used for discrimination by answering the following questions:

a. What algorithm is used for discrimination (e.g., multi-layer perception, support vector machine, etc.)? The primary algorithm is an analysis of the inverted permeabilities and the lengths and widths of the spheroid models produced by the inversion and then a comparison to coefficients for known items including those from the Calibration grid and test stand data.

b. Why is this algorithm used and not others? This discrimination analysis process has been used successfully for the ALLTEM for UXO items.

c. Which parameters are considered as possible inputs to the algorithm? Permeabilities (composition of target material) and dimensions of the prolate spheroid resulting from the inversion analysis.

d. What are the outputs of the algorithm (probabilities, confidence levels)? Multiple probabilities of classification with associated confidence levels are derived for a given target item. These probabilities represent the likelihood of an item being clutter or ordnance and the most likely types of ordnance.

e. How is the threshold set to decide where the munitions/non-munitions line lies in the discrimination process? The threshold used to determine UXO vs clutter is based on the ratio of the spheroid dimensions. For a rod-like item, the two smaller widths should be similar and much smaller than the third, much larger, length. Clutter typically does not follow this pattern although some can.

Training: This section should include the details of how training data is used to make a decision on the likelihood of the anomaly correspondence to munitions. Please answer the following questions:

a. Which tunable parameters have final values that are optimized over a training set of data and which have values that are set according to geophysical knowledge (i.e., intuition, experience, common sense)? Training data is used to tune estimates of location, depth, spheroid dimensions, time decay constants, and composition analysis. Geophysical knowledge comes in when deciding that a rod-like, sphere-like, or disk-like object is a UXO versus a piece of clutter.

(1) For those tunable parameters with final values set according to geophysical knowledge:

(a) What is the reasoning behind choosing these particular values? These shapes (rod, sphere, disk) seem to be the typical type of ordnance used on training ranges.

(b) Why were the final values not optimized over a training set of data? While the final values are optimized over a training set of data, they are, to a large degree, based on a priori site specific data at a given site.

(2) For those tunable parameters with final values optimized over the training set data:

(a) What training data is used (e.g., all data, a randomly chosen portion of data, etc.)? All available data is utilized to train the inversion and classification algorithms.

(b) What error metric is minimized during training (e.g., mean squared error, etc.)? Inferred composition analysis and definition of an ordnance by its spheroid equivalent dimensions and time decay..

(c) What learning rule is used during training (e.g., gradient descent, etc.)? Determine best parameters to identify and characterize various ordnance versus clutter.

(d) What criterion is used to stop training (e.g., number of iterations exceeds threshold, good generalization over validation set of data, etc.)? Criterion is limit of the number of training items. The more known items available the better the statistical analysis of the possible variations for a given type of ordnance.

(e) Are all tunable parameters optimized at once or in sequence ("in sequence" = parameters 1 is held constant at some common sense values while parameter 2 is optimized, and then parameter 2 is held constant at its optimized value while parameter 1 is optimized)? Tunable parameters are optimized in sequence.

b. What are the final values of all tunable parameters for the characterization process? The final values for the characterization are the correctly classified targets.

2.1.4 Data Submission Format

Data were submitted for scoring in accordance with data submission protocols outlined on the USAEC Web site www.uxotestsites.org. These submitted data are not included in this report in order to protect GT information.

2.1.5 Demonstrator Quality Assurance (QA) and Quality Control (QC) (provided by demonstrator)

Overview of Quality Control (QC): The ALLTEM system has a real-time data display that instantly shows the operator if the transmitting/receiving functions of the system fail. In addition, we plan to find a location with no known targets and repetitively reoccupy that location and record data, including GPS data, to assess and document any drifts that may occur in the instrumentation. Standard operating procedure with all these systems is to occupy a designated clean location at least twice each day: prior to and at the completion of regular data acquisition. This usually takes place in the morning and afternoon, but in case of an extended pause in the middle of the day, an additional reference data set may be acquired. This will also test the

accuracy and repeatability of the navigation data. As with all analog and time-base systems, drift will occur mainly due to component tolerances and temperature dependencies. This inherent system drift limits the absolute accuracy of the measurements that can be attained. The reference data are used primarily as a metric for overall accuracy. Abnormal drift, as would be caused by battery depletion or component degradation, would trigger a system check and data review. The hardware problem would be corrected and field data acquisition would resume. Any previous data deemed degraded would be reacquired. We also plan to preprocess data overnight or concurrent with data acquisition to visually ensure that there are no serious “glitches” or “tears” in the data. Any corrupted lines will be repeated. The GPS will be referenced to a local geodetic marker.

Overview of Quality Assurance (QA): As mentioned above, the planned along-line data density will be around 15 to 20 cm with a line spacing of 50 cm. This will ensure that the 1-meter square antennas will sample over every point on the ground. The basic position accuracy of our real-time kinematic differential GPS system is better than 2 cm when operating in “fixed” mode. The LabVIEW program reads the GPS data and mode. If the mode is not fixed, the LabVIEW program flashes a visual warning on the monitor to alert the operator that the GPS is not in fixed mode. However, after our recent experience with radio communications problems at YPG, we now record to memory cards the raw data at both the GPS rover and base stations and then post-process the data to correct locations. Other sources of error in positioning, such as GPS data latency, GPS antenna-to-sensor offset, and tilting of the GPS antenna mast with topography degrade absolute position accuracy. We have added an Attitude Heading and Reference System (AHRS) to measure the cart orientation relative to the ground. We have also developed a navigation program in LabView that runs concurrent with the acquisition program to maintain position over large distances.

Data processing will begin in the field. At the end of each survey line, the data is automatically copied to an external hard drive which will be swapped out with another drive periodically during the survey. The data is then quickly batch processed in Geosoft Oasis Montaj and within minutes the quality of the survey data density and areal coverage can be evaluated.

2.1.6 Additional Records

The following record(s) by this vendor can be accessed via the Internet as Microsoft Word documents at www.uxotestsites.org.

2.2 APG SITE INFORMATION

2.2.1 Location

The APG Standardized Test Site is located within a secured range area of the Aberdeen Area. The Aberdeen Area of APG is located approximately 30 miles northeast of Baltimore at the northern end of the Chesapeake Bay. The Standardized Test Site encompasses 17 acres of upland and lowland flats, woods, and wetlands.

2.2.2 Soil Type

According to the soils survey conducted for the entire area of APG in 1998, the test site consists primarily of Elkton Series type soil (ref 2). The Elkton Series consist of very deep, slowly permeable, poorly drained soils. These soils formed in silty aeolin sediments and the underlying loamy alluvial and marine sediments. They are on upland and lowland flats and in depressions of the Mid-Atlantic Coastal Plain. Slopes range from 0 to 2 percent.

ERDC conducted a site-specific analysis in May 2002 (ref 3). The results basically matched the soil survey mentioned above. Seventy percent of the samples taken were classified as silty loam. The majority (77 percent) of the soil samples had a measured water content between 15 and 30 percent with the water content decreasing slightly with depth.

For more details concerning the soil properties at the APG test site, go to www.uxotestsites.org on the Web to view the entire soils description report.

2.2.3 Test Areas

A description of the test site areas at APG is presented in Table 1. A test site layout is shown in Figure 2.

TABLE 1. TEST SITE AREAS

Area	Description
Calibration lanes	Contains 14 standard munitions items buried in six positions, with representation of clutter, at various angles and depths to allow demonstrators to calibrate their equipment.
Blind grid	Contains 400 grid cells in a 0.5-acre site. The center of each grid cell contains either munitions, clutter, or nothing.
Open field	A 10-acre site composed of generally open and flat terrain with minimal clutter and minor navigational obstacles. Vegetation height varies from 15 to 25 cm. This area is subdivided into four subareas (legacy, direct fire, indirect fire, and challenge).
	• *Open field (legacy)* The legacy subarea contains the same wide variety of randomly-placed munitions that were present in the open field prior to the January 2008 general reconfiguration of the site.
	• *Open field (direct fire)* The direct fire subarea contains only three munition types that could be typically found at an impact area of a direct fire weapons range. Munitions and clutter are placed in a pattern typical for these munitions.
	• *Open field (indirect fire)* The indirect fire subarea contains only three munition types that could be typically found at an impact area of an indirect fire weapons range. Munitions and clutter are placed in a pattern typical for these munitions.
	• *Open field (challenge)* The challenge subarea is easily reconfigurable to meet the specific needs and requirements of the demonstrator or the program sponsor. Any results from this area are not reported in the standardized scoring record.
Woods	1.34-acre area consisting of cleared woods (tree removal with only stumps remaining), partially cleared woods (including all underbrush and fallen trees), and virgin woods (i.e., woods in natural state with all trees, underbrush, and fallen trees left in place).
Moguls	1.30-acre area consisting of two areas (the rectangular or driving portion of the course and the triangular section with more difficult, nondrivable terrain). A series of craters (as deep as 0.91 m) and mounds (as high as 0.91 m) encompass this section.

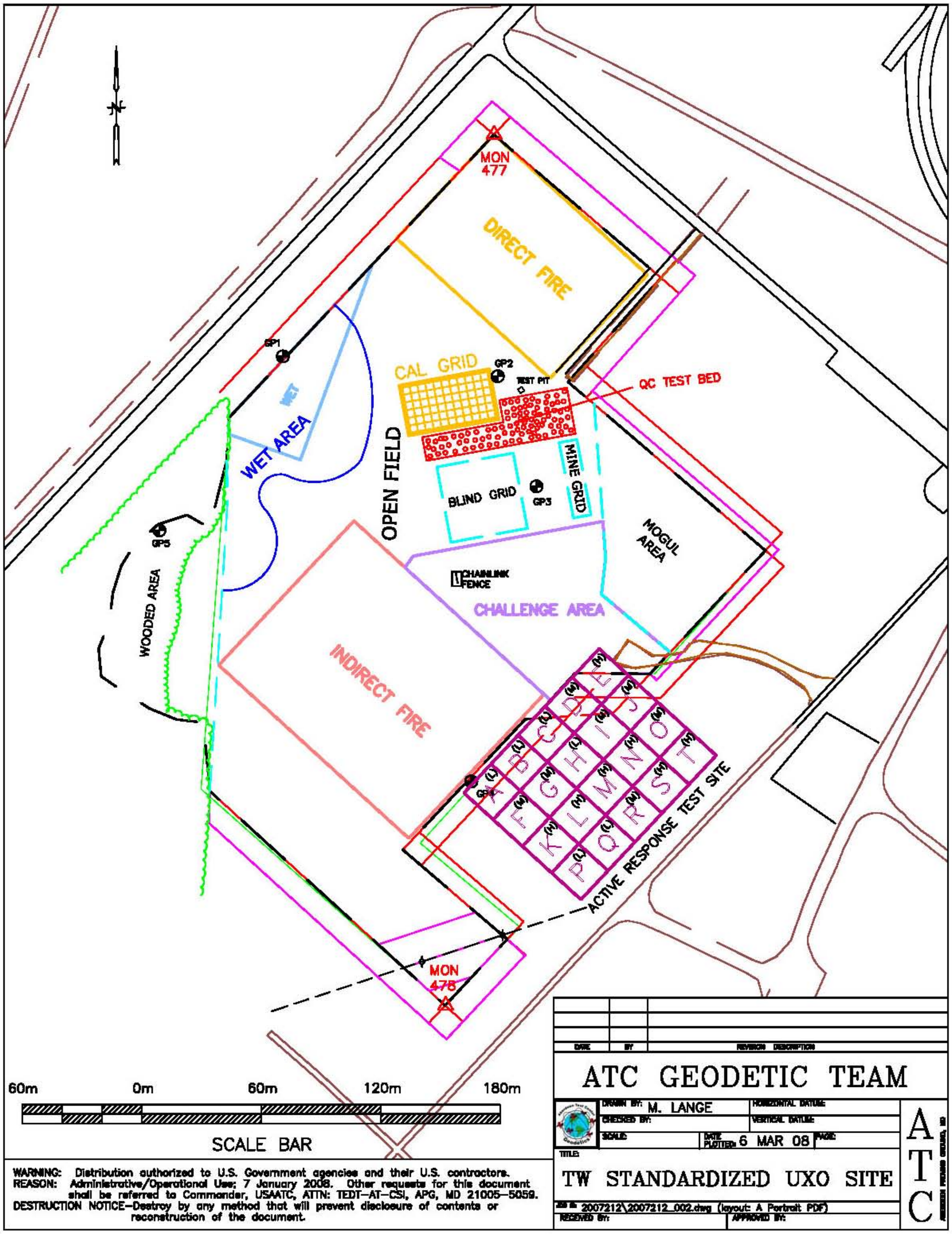


Figure 2. Test site layout.

2.2.4 Standard and Nonstandard Inert Munitions Targets

The standard and nonstandard munitions items emplaced in the test areas are presented in Table 2. Standardized targets are members of a set of specific munitions items that have identical properties to all other items in the set (caliber, configuration, size, weight, aspect ratio, material, filler, magnetic remanence, and nomenclature). Nonstandard targets are inert munitions items having properties that differ from those in the set of standardized items.

TABLE 2. INERT MUNITIONS TARGETS

Item	Munition Type	Calibration Lanes	Blind Grid	Open Field Direct Fire	Open Field Indirect Fire	Open Field Legacy	Moguls	Woods
20-mm Projectile M55	S	X				X	X	X
25-mm Projectile M794	S	X	X	X				
37-mm Projectile M47	S	X	X	X				
40-mm Projectile MKII Bodies	S	X				X	X	X
BDU-28 Submunition	S	X				X	X	X
BLU-26 Submunition	S	X				X	X	X
M42 Submunition	S	X				X	X	X
57-mm Projectile APC M86	S	X				X	X	X
60-mm Mortar M49A3	S	X	X		X			
2.75-in. Rocket M230	S	X				X	X	X
81-mm Mortar M374	S	X	X		X	X	X	X
105-mm HEAT Rounds M456	S					X	X	X
105-mm HEAT Round M490	S	X	X	X				
105-mm Projectile M60	S	X	X		X	X	X	X
155-mm Projectile M483A1	S	X				X	X	X
20-mm Projectile M55	NS					X	X	X
20-mm Projectile M97	NS					X	X	X
40-mm Projectile M813	NS					X	X	X
60-mm Mortar (JPG)	NS					X	X	X
60-mm Mortar M49	NS					X	X	X
2.75-in. Rocket M230	NS					X	X	X
2.75-in. Rocket XM229	NS					X	X	X
81-mm Mortar (JPG)	NS					X	X	X
81-mm Mortar M374	NS					X	X	X
105-mm Projectile M60	NS					X	X	X
155-mm Projectile M483A	NS					X	X	X

HEAT = high-explosive antitank.
JPG = Jefferson Proving Ground.
NS = Nonstandard munition.
S = Standard munition.

2.3 ATC SURVEY COMMENTS

Survey of the Open Field (Indirect Fire Area) was only partially completed.

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES (2 to5, 8 to10 March 2010)

3.2 AREAS TESTED/NUMBER OF HOURS

Areas tested and total numbers of hours operated at each site are presented in Table 3.

TABLE 3. AREAS TESTED AND NUMBER OF HOURS

Area	Number of Hours
Calibration lanes	4.08
Blind grid	5.92
Open field	36.33
Woods	-
Mogul	-
Mine grid	-

Note: Table 3 represents the total time spent in each area.

3.3 TEST CONDITIONS

3.3.1 Weather Conditions

An APG weather station located approximately 1 mile west of the test site was used to record average temperature and precipitation on a half-hour basis for each day of operation. The temperatures presented in Table 4 represent the average temperature during field operations from 0700 to 1700 hours, while precipitation data represent a daily total amount of rainfall. Hourly weather logs used to generate this summary are provided in Appendix B.

TABLE 4. TEMPERATURE/PRECIPITATION DATA SUMMARY

Date, 2010	Average Temperature, ^{o}F	Total Daily Precipitation, in.
2 March	40.4	0.08
3 March	40.4	0.02
4 March	41.8	0.00
5 March	43.1	0.00
8 March	51.8	0.00
9 March	55.0	0.00
10 March	50.9	0.00

3.3.2 Field Conditions

USGS surveyed the calibration grid, blind grid, direct and indirect fire areas. The field was wet in all areas of the field due to rain and snow prior to testing. USGS was unable to complete a small portion of the indirect fire area due to standing water.

3.3.3 Soil Moisture

Three soil probes were placed at various locations within the site to capture soil moisture data: blind grid, calibration, open field, and wooded areas. Measurements were collected in percent moisture and were taken twice daily (morning and afternoon) from five different soil depths (1 to 6 in., 6 to 12 in., 12 to 24 in., 24 to 36 in., and 36 to 48 in.) from each probe. Soil moisture logs are provided in Appendix C.

3.4 FIELD ACTIVITIES

3.4.1 Setup/Mobilization

These activities included initial mobilization and daily equipment preparation and breakdown. A three-person crew took 5 hours and 40 minutes to perform the initial setup and mobilization. A total of 5 hours and 20 minutes of equipment preparation was accrued, and end of day equipment breakdown totaled 2 hours.

3.4.2 Calibration

USGS spent a total of 4 hours 5 minutes in the calibration lanes, of which 2 hours and 30 minutes were spent collecting data. Numerous calibration exercises occurred while surveying the Blind Grid and Open Field lasting 4 hours and 5 minutes.

3.4.3 Downtime Occasions

Occasions of downtime are grouped into five categories: equipment/data checks or equipment maintenance, equipment failure and repair, weather, demonstration site issues, or breaks/lunch. All downtime is included for the purposes of calculating labor requirements (section 5) except for downtime due to demonstration site issues. Demonstration site issues, while noted in the daily log, are considered nonchargeable downtime for the purposes of calculating labor costs and are not discussed. Breaks and lunches are discussed in this section and billed to the total site survey area.

3.4.3.1 Equipment/data checks, maintenance. Equipment data checks and maintenance activities accounted for 1 hour and 35 minutes of site usage time. These activities included changing out batteries and performing routine data checks to ensure the data were being properly recorded/collected. USGS spent 1 hour and 20 minutes for breaks and lunches.

3.4.3.2 Equipment failure or repair. Two equipment failures occurred during this survey totaling 1 hour and 40 minutes. A faulty GPS cable had to be repaired. Also, USGS had two incidents of flat tires while surveying. All repairs were made on site.

3.4.3.3 Weather. No weather delays occurred during the survey.

3.4.4 Data Collection

TABLE 5. TOTAL TIME NRL, SPENT PER AREA

Area	Time, hr/min
Blind grid	3 hours/50 minutes
Open field	--
Legacy	--
Direct fire	8 hours/15 minutes
Indirect fire	13 hours/5 minutes
Challenge	--
Wooded	--
Mine Grid	--
Moguls	--

Note: Table 5 represents the total time spent in each area collecting data.

3.4.5 Demobilization

The USGS survey crew conducted a demonstration of the calibration, blind grid, and open field, indirect/direct fire areas. Demobilization occurred on 10 March 2010. On that day, it took the crew 3 hours and 10 minutes to break down and pack up their equipment.

3.5 PROCESSING TIME

USGS submitted the raw data from the demonstration activities on the last day of the demonstration, as required. The initial scoring submittal data was provided September 2010. However, the final submittal for scoring was provided March 2011.

3.6 DEMONSTRATOR'S FIELD PERSONNEL

Ted Asch
Craig Moulton
Moustapha Sylla

3.7 DEMONSTRATOR'S FIELD SURVEYING METHOD

USGS collected the data in a linear fashion, using a line spacing the width of the array.

3.8 SUMMARY OF DAILY LOGS

Daily logs capture all field activities during this demonstration and are provided in Appendix D.

SECTION 4. TECHNICAL PERFORMANCE RESULTS

4.1 ROC CURVES USING ALL MUNITIONS CATEGORIES

The probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of clutter detection or probability of false positive within each area are shown in Figures 3 through 8. The probabilities plotted against their respective background alarm rate within each area are shown in Figures 9 through 14. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination.

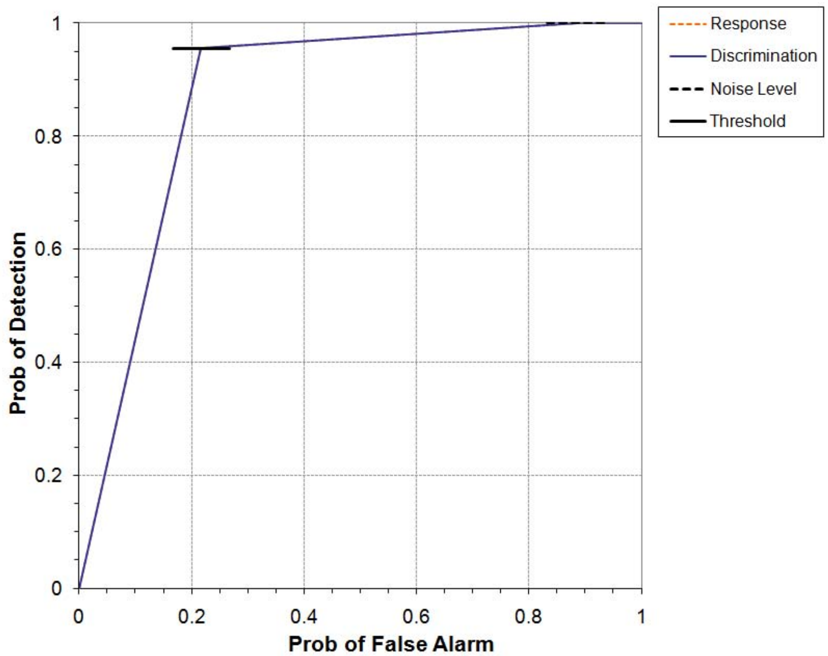


Figure 3. ALLTEM/towed blind grid probability of detection for response and discrimination stages versus their respective probability of false positive.

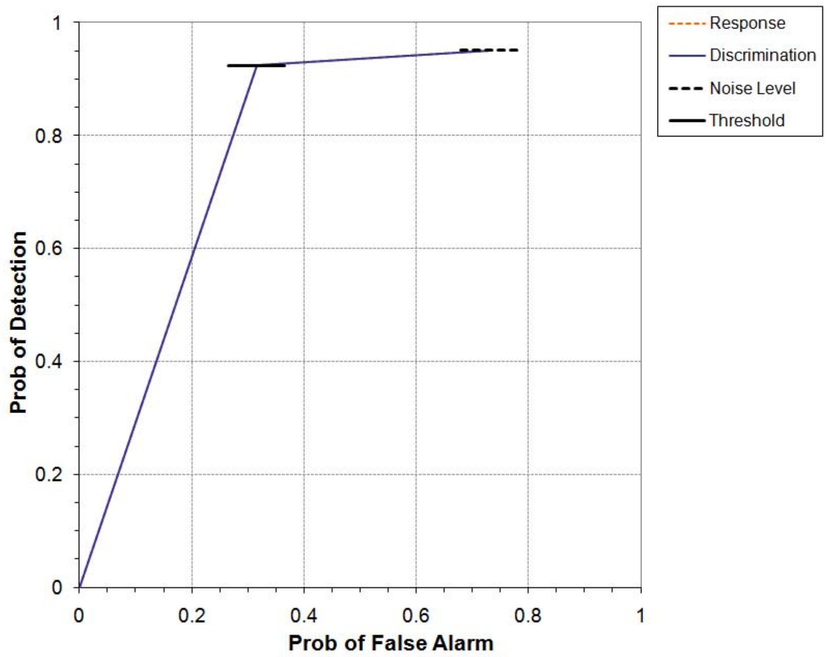


Figure 4. ALLTEM/towed open field (direct fire) probability of detection for response and discrimination stages versus their respective probability of false positive.

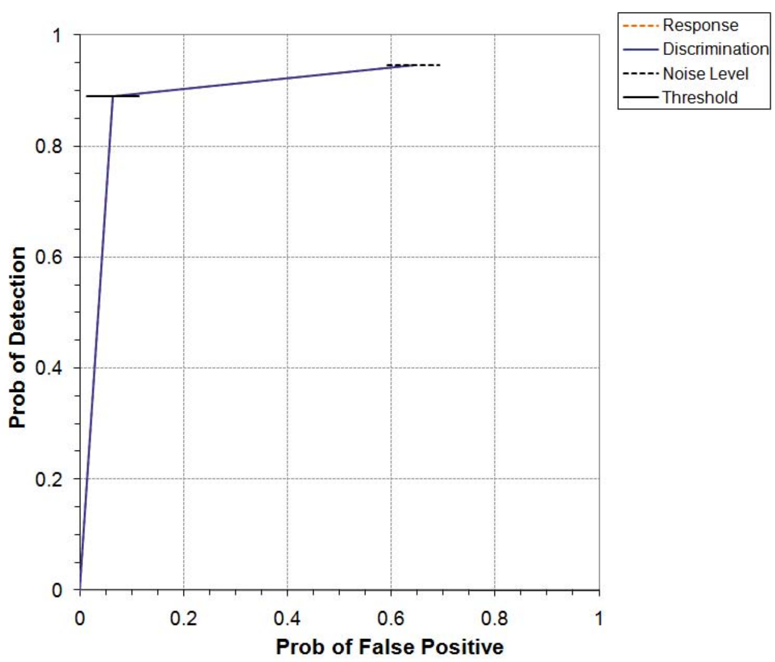


Figure 5. ALLTEM/towed open field (indirect fire) probability of detection for response and discrimination stages versus their respective probability of false positive.

Not covered

Figure 6. ALLTEM/towed open field (legacy) probability of detection for response and discrimination stages versus their respective probability of false positive.

Not covered

Figure 7. ALLTEM/towed wooded probability of detection for response and discrimination stages versus their respective probability of false positive.

Not covered

Figure 8. ALLTEM/towed mogul probability of detection for response and discrimination stages versus their respective probability of false positive.

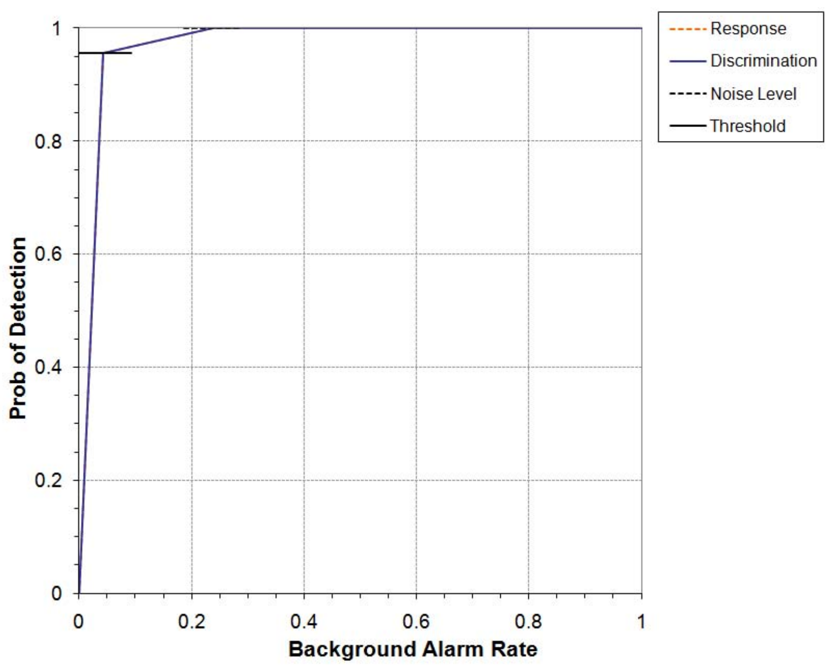


Figure 9. ALLTEM/towed blind grid probability of detection for response and discrimination stages versus their respective probability of background alarm.

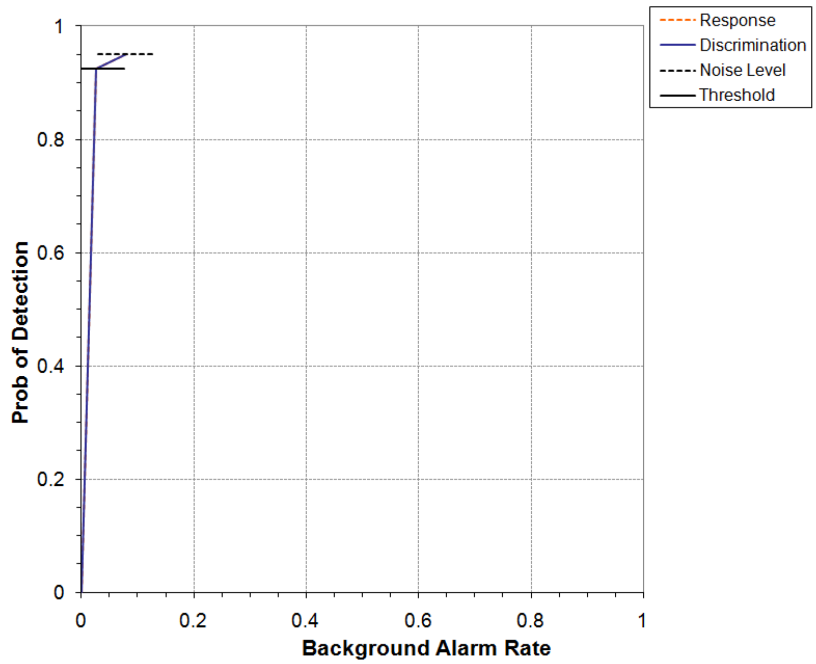


Figure 10. ALLTEM/towed open field (direct fire) probability of detection for response and discrimination stages versus their respective background alarm rate.

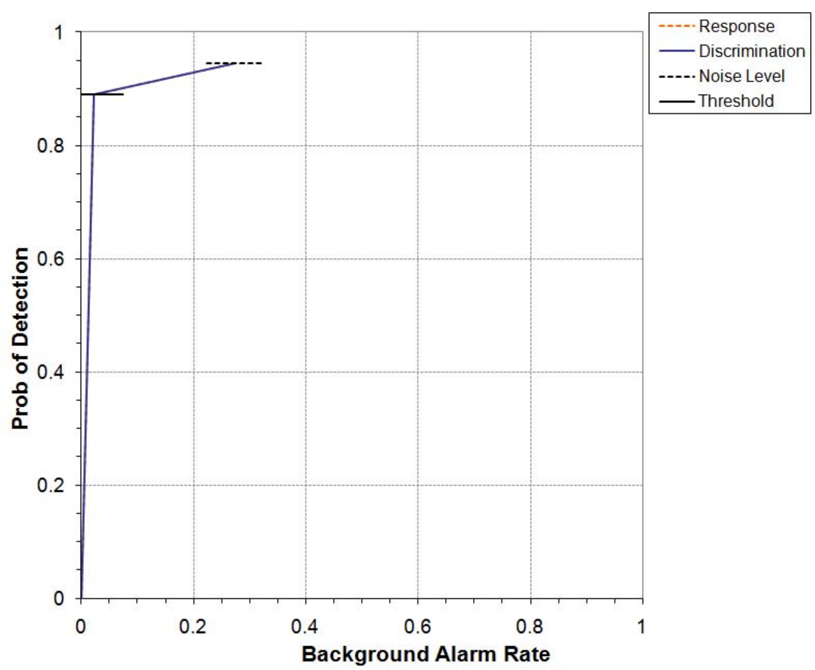


Figure 11. ALLTEM/towed open field (indirect fire) probability of detection for response and discrimination stages versus their respective background alarm rate.

Not covered

Figure 12. ALLTEM/towed open field (legacy) probability of detection for response and discrimination stages versus their respective background alarm rate.

Not covered

Figure 13. ALLTEM/towed wooded probability of detection for response and discrimination stages versus their respective background alarm rate.

Not covered

Figure 14. ALLTEM/towed mogul probability of detection for response and discrimination stages versus their respective background alarm rate.

4.2 PERFORMANCE SUMMARIES

Results for each of the testing areas are presented in Tables 6 (for labor requirements, see section 5). The response stage results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the discrimination stage are derived from the demonstrator's recommended threshold for optimizing munitions related cleanup by minimizing false alarm digs and maximizing munitions recovery. The lower and upper 90-percent confidence limits on P_d, P_{cd}, and P_{fp} were calculated assuming that the number of detections and false positives are binomially distributed random variables.

TABLE 6a. BLIND GRID TEST AREA RESULTS

	Response Stage				Discrimination Stage			
Munitions[a] Scores	***P_d^{res}: by type***				***P_d^{disc}: by type***			
	All Types	**105-mm**	**81/60-mm**	**37/25-mm**	**All Types**	**105-mm**	**81/60-mm**	**37/25-mm**
	1.00 1.00 0.98	1.00 1.00 0.93	1.00 1.00 0.93	1.00 1.00 0.93	0.98 0.96 0.91	1.00 0.97 0.88	0.98 0.93 0.83	1.00 0.97 0.88
By Depth[b]								
0 to 4D	1.00	1.00	1.00	1.00	0.96	1.00	0.92	1.00
4D to 8D	1.00	1.00	1.00	1.00	0.97	1.00	1.00	0.95
8D to 12D	1.00	1.00	1.00	1.00	0.89	0.83	1.00	1.00
Clutter Scores	***P_{cd}***				***P_{fp}***			
By Mass								
By Depth[b]	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**
All Depth	0.92 0.88 0.84	0.76	1.00	1.00	0.27 0.22 0.17	0.12	0.27	0.50
0 to 0.15 m	0.89	0.77	1.00	1.00	0.21	0.11	0.27	0.67
0.15 to 0.3 m	0.88	0.60	1.00	1.00	0.25	0.20	0.29	0.25
0.3 to 0.6 m	NA	NA	NA	NA	NA	NA	NA	NA
Background Alarm Rates								
	P_{ba}^{res}: 0.24				**P_{ba}^{disc}:** 0.04			

[a]In cells with offset data entries, the numbers to the left are the result and the two numbers to the right are an upper and lower 90-percent confidence interval for an assumed binomial distribution.
[b]All depths are measured to the center of the object.

TABLE 6b. OPEN FIELD DIRECT FIRE TEST AREA RESULTS

	Response Stage				Discrimination Stage			
Munitions[a] Scores	***P_d^{res}: by type***				***P_d^{disc}: by type***			
	All Types	**105-mm**	**37-mm**	**25-mm**	**All Types**	**105-mm**	**37-mm**	**25-mm**
	0.97 0.95 0.93	0.98 0.95 0.91	0.97 0.93 0.89	0.99 0.97 0.93	0.95 0.93 0.90	0.95 0.92 0.86	0.96 0.92 0.87	0.97 0.94 0.89
By Density								
High	0.94	0.96	0.89	0.96	0.91	0.96	0.85	0.92
Medium	0.97	1.00	0.93	0.97	0.93	0.93	0.93	0.94
Low	0.95	0.90	0.97	0.97	0.93	0.86	0.97	0.94
By Depth[b]								
0 to 4D	0.96	1.00	0.94	1.00	0.94	1.00	0.92	0.92
4D to 8D	0.96	0.96	0.92	0.98	0.94	0.93	0.92	0.96
8D to 12D	0.91	0.89	0.00	0.92	0.84	0.78	0.00	0.88
Clutter Scores	***P_{cd}***				***P_{fp}***			
By Mass								
By Depth[b]	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**
All Depth	0.76 0.73 0.69	0.57	0.86	0.96	0.36 0.32 0.28	0.13	0.46	0.52
0 to 0.15 m	0.73	0.59	0.87	0.95	0.31	0.14	0.50	0.45
0.15 to 0.3 m	0.69	0.54	0.75	1.00	0.24	0.08	0.13	0.60
0.3 to 0.6 m	0.80	0.00	1.00	1.00	0.70	0.00	0.00	1.00
Background Alarm Rates								
	BAR^{res}: 0.11				**BAR^{disc}:** 0.04			
Groups								
Found	0.94				0.88			
Identified	0.12				0.06			
Coverage	0.53				0.47			

[a]In cells with offset data entries, the numbers to the left are the result and the two numbers to the right are an upper and lower 90-percent confidence interval for an assumed binomial distribution.
[b]All depths are measured to the center of the object.

TABLE 6c. OPEN FIELD INDIRECT FIRE TEST AREA RESULTS

	Response Stage				Discrimination Stage			
Munitions[a] Scores	P_d^{res}: *by type*				P_d^{disc}: *by type*			
	All Types	**105-mm**	**81-mm**	**60-mm**	**All Types**	**105-mm**	**81-mm**	**60-mm**
	0.96 0.95 0.92	0.99 0.97 0.92	0.96 0.93 0.87	0.97 0.94 0.90	0.92 0.89 0.86	0.97 0.94 0.90	0.87 0.82 0.75	0.95 0.91 0.86
By Density								
High	0.90	0.92	0.86	0.92	0.86	0.92	0.86	0.80
Medium	0.93	1.00	0.89	0.90	0.87	0.97	0.75	0.90
Low	0.99	0.97	1.00	1.00	0.93	0.93	0.84	1.00
By Depth[b]								
0 to 4D	0.97	1.00	0.97	0.95	0.93	0.96	0.88	0.92
4D to 8D	0.93	0.97	0.90	0.93	0.91	0.97	0.85	0.93
8D to 12D	0.84	0.50	0.89	0.92	0.64	0.50	0.44	0.83
Clutter Scores	P_{cd}				P_{fp}			
By Mass								
By Depth[b]	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**
All Depth	0.68 0.64 0.61	0.50	0.79	0.84	0.08 0.06 0.05	0.04	0.05	0.21
0 to 0.15 m	0.62	0.50	0.78	0.83	0.07	0.05	0.06	0.35
0.15 to 0.3 m	0.75	0.63	0.79	0.82	0.02	0.00	0.00	0.06
0.3 to 0.6 m	0.82	0.00	0.83	1.00	0.00	0.00	0.00	0.00
Background Alarm Rates								
	BAR^{res}: 0.27				**BAR^{disc}:** 0.02			
Groups								
Found	0.95				0.80			
Identified	0.00				0.00			
Coverage	0.47				0.40			

[a]In cells with offset data entries, the numbers to the left are the result and the two numbers to the right are an upper and lower 90-percent confidence interval for an assumed binomial distribution.
[b]All depths are measured to the center of the object.

Note: This Results Table was scored using a subset of the full Open Field (Indirect Fire) Ground Truth, therefore these results cannot be directly compared to any other APG Open Field (Indirect Fire) Results reported.

TABLE 6d. OPEN FIELD LEGACY TEST AREA RESULTS (not covered)

	Response Stage					Discrimination Stage				
Munitions[a] Scores	P_d^{res}: *by type*					P_d^{disc}: *by type*				
	All Types	**Small**	**Medium**	**Large**		**All Types**	**Small**	**Medium**	**Large**	
	-- -- --	-- -- --	-- -- --	-- -- --		-- -- --	-- -- --	-- -- --	-- -- --	
By Depth[b]										
0 to 4D	--	--	--	--		--	--	--	--	
4D to 8D	--	--	--	--		--	--	--	--	
8D to 12D	--	--	--	--		--	--	--	--	
> 12D	--	--	--	--		--	--	--	--	
Clutter Scores	P_{cd}					P_{fp}				
By Mass										
By Depth[b]	**All Mass**	0 to 0.25 kg	**>0.25 to 1 kg**	**>1 to 10 kg**	**> 10 kg**	**All Mass**	0 to 0.25 kg	**>0.25 to 1 kg**	**>1 to 8 kg**	**< 10kg**
All Depth	-- -- --	--	--	--	--	-- -- --	--	--	--	--
0 to 0.15 m	--	--	--	--	--	--	--	--	--	--
0.15 to 0.3 m	--	--	--	--	--	--	--	--	--	--
0.3 to 0.6 m	--	--	--	--	--	--	--	--	--	--
> 0.6 m	--	--	--	--	--	--	--	--	--	--
Background Alarm Rates										
	BAR[res]:					**BAR[disc]:**				
Groups										
Found	--					--				
Identified	--					--				
Coverage	--					--				

[a]In cells with offset data entries, the numbers to the left are the result and the two numbers to the right are an upper and lower 90-percent confidence interval for an assumed binomial distribution.

[b]All depths are measured to the center of the object.

TABLE 6e. WOODED TEST AREA RESULTS (not covered)

	Response Stage				Discrimination Stage			
Munitions[a] Scores	P_d^{res}: *by type*				P_d^{disc}: *by type*			
	All Types	**Small**	**Medium**	**Large**	**All Types**	**Small**	**Medium**	**Large**
	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
By Depth[b]								
0 to 4D	--	--	--	--	--	--	--	--
4D to 8D	--	--	--	--	--	--	--	--
8D to 12D	--	--	--	--	--	--	--	--
> 12D	--	--	--	--	--	--	--	--

Clutter Scores	P_{cd}					P_{fp}				
	By Mass									
By Depth[b]	**All Mass**	0 to 0.25 kg	**>0.25 to 1 kg**	**>1 to 10 kg**	**> 10 kg**	**All Mass**	0 to 0.25 kg	**>0.25 to 1 kg**	**>1 to 8 kg**	**< 10kg**
All Depth	-- -- --	--	--	--	--	-- -- --	--	--	--	--
0 to 0.15 m	--	--	--	--	--	--	--	--	--	--
0.15 to 0.3 m	--	--	--	--	--	--	--	--	--	--
0.3 to 0.6 m	--	--	--	--	--	--	--	--	--	--
> 0.6 m	--	--	--	--	--	--	--	--	--	--

	Background Alarm Rates	
	BAR^{res}:	**BAR^{disc}:**
	Groups	
Found	--	--
Identified	--	--
Coverage	--	--

[a]In cells with offset data entries, the numbers to the left are the result and the two numbers to the right are an upper and lower 90-percent confidence interval for an assumed binomial distribution.
[b]All depths are measured to the center of the object.

TABLE 6f. MOGUL TEST AREA RESULTS (not covered)

	Response Stage				Discrimination Stage			
Munitions[a] Scores	***P_d^{res}: by type***				***P_d^{disc}: by type***			
	All Types	**Small**	**Medium**	**Large**	**All Types**	**Small**	**Medium**	**Large**
	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
By Depth[b]								
0 to 4D	--	--	--	--	--	--	--	--
4D to 8D	--	--	--	--	--	--	--	--
8D to 12D	--	--	--	--	--	--	--	--
> 12D	--	--	--	--	--	--	--	--

	Response Stage					Discrimination Stage				
Clutter Scores	***P_{cd}***					***P_{fp}***				
By Mass										
By Depth[b]	**All Mass**	0 to 0.25 kg	**>0.25 to 1 kg**	**>1 to 10 kg**	**> 10 kg**	**All Mass**	0 to 0.25 kg	**>0.25 to 1 kg**	**>1 to 8 kg**	**< 10kg**
All Depth	-- -- --	--	--	--	--	-- -- --	--	--	--	--
0 to 0.15 m	--	--	--	--	--	--	--	--	--	--
0.15 to 0.3 m	--	--	--	--	--	--	--	--	--	--
0.3 to 0.6 m	--	--	--	--	--	--	--	--	--	--
> 0.6 m	--	--	--	--	--	--	--	--	--	--
Background Alarm Rates										
	BAR^{res}:					**BAR^{disc}:**				
Groups										
Found	--					--				
Identified	--					--				
Coverage	--					--				

[a]In cells with offset data entries, the numbers to the left are the result and the two numbers to the right are an upper and lower 90-percent confidence interval for an assumed binomial distribution.
[b]All depths are measured to the center of the object.

4.3 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION

Efficiency and rejection rates are calculated to quantify the discrimination ability at specific points of interest on the ROC curve: (1) at the point where no decrease in P_d is suffered (i.e., the efficiency is by definition equal to one) and (2) at the operator selected threshold. These values are presented in Tables 7a through 7d.

TABLE 7a. BLIND GRID EFFICIENCY AND REJECTION RATES

	Efficiency (E)	**False Positive Rejection Rate**	**Background Alarm Rejection Rate**
At Operating Point	0.96	0.75	0.82
With No Loss of P_d	1.00	0.00	0.00

TABLE 7b. OPEN FIELD (DIRECT) EFFICIENCY AND REJECTION RATES

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	0.97	0.57	0.68
With No Loss of P_d	1.00	0.00	0.00

TABLE 7c. OPEN FIELD (INDIRECT) EFFICIENCY AND REJECTION RATES

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	0.94	0.90	0.92
With No Loss of P_d	1.00	0.00	0.00

Note: This Results Table was scored using a subset of the full Open Field (Indirect Fire) Ground Truth, therefore these results cannot be directly compared to any other APG Open Field (Indirect Fire) Results reported.

TABLE 7d. OPEN FIELD (LEGACY) EFFICIENCY AND REJECTION RATES (not covered)

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejion Rate
At Operating Point	--	--	--
With No Loss of P_d	--	--	--

TABLE 7e. WOODED EFFICIENCY AND REJECTION RATES (not covered)

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	--	--	--
With No Loss of P_d	--	--	--

TABLE 7f. MOGUL EFFICIENCY AND REJECTION RATES (not covered)

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	--	--	--
With No Loss of P_d	--	--	--

At the demonstrator's recommended setting, the munitions items that were detected and correctly discriminated were further scored on whether their correct type could be identified (table 8a through 8f). Correct type examples include 20-mm projectile, 105-mm HEAT projectile, and 2.75-inch Rocket. A list of the standard type declaration required for each munitions item was provided to demonstrators prior to testing. The standard types for the three example items are 20-mmP, 105H, and 2.75-inch.

TABLE 8a. BLIND GRID CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS MUNITIONS

Size	Percentage Correct, %
25mm	40
37mm	100
60mm	87
81mm	73
105mm	13
105 artillery	100
Overall	69

TABLE 8b. OPEN FIELD DIRECT FIRE CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS MUNITIONS

Size	Percentage Correct, %
25mm	64
37mm	70
105mm	92
Overall	75

TABLE 8c. OPEN FIELD INDIRECT FIRE CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS MUNITIONS

Size	Percentage Correct, %
60 mm	78
81 mm	69
105 mm	92
Overall	80

Note: This Results Table was scored using a subset of the full Open Field (Indirect Fire) Ground Truth, therefore these results cannot be directly compared to any other APG Open Field (Indirect Fire) Results reported.

TABLE 8d. OPEN FIELD LEGACY CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS MUNITIONS (not covered)

Size	Percentage Correct
Small	--
Medium	--
Large	--
Overall	--

TABLE 8e. WOODED CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS MUNITIONS (not covered)

Size	Percentage Correct
Small	--
Medium	--
Large	--
Overall	--

TABLE 8f. MOGUL CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS MUNITIONS (not covered)

Size	Percentage Correct
Small	--
Medium	--
Large	--
Overall	--

4.4 LOCATION ACCURACY

The mean location error and standard deviations appear in Tables 9a through 9f. These calculations are based on average missed distance for munitions correctly identified during the response stage. Depths are measured from the center of the munitions to the surface. For the blind grid, only depth errors are calculated because (X, Y) positions are known to be the centers of the grid square.

TABLE 9a. BLIND GRID MEAN LOCATION ERROR AND STANDARD DEVIATION

	Mean	Standard Deviation
Northing	NA	NA
Easting	NA	NA
Depth	0.00	0.09

TABLE 9b. OPEN FIELD DIRECT FIRE MEAN LOCATION ERROR AND STANDARD DEVIATION

	Mean	Standard Deviation
Northing	0.00	0.09
Easting	-0.05	0.10
Depth	0.00	0.09

TABLE 9c. OPEN FIELD INDIRECT FIRE MEAN LOCATION ERROR AND STANDARD DEVIATION

	Mean	Standard Deviation
Northing	0.01	0.10
Easting	-0.05	0.10
Depth	0.00	0.09

TABLE 9d. OPEN FIELD LEGACY MEAN LOCATION ERROR AND STANDARD DEVIATION (not covered)

	Mean	Standard Deviation
Northing	--	--
Easting	--	--
Depth	--	--

TABLE 9e. WOODED MEAN LOCATION ERROR AND STANDARD DEVIATION (not covered)

	Mean	Standard Deviation
Northing	--	--
Easting	--	--
Depth	--	--

TABLE 9f. MOGUL MEAN LOCATION ERROR AND STANDARD DEVIATION (not covered)

	Mean	Standard Deviation
Northing	--	--
Easting	--	--
Depth	--	--

SECTION 5. APPENDIXES

APPENDIX A. TERMS AND DEFINITIONS

GENERAL DEFINITIONS

Anomaly: Location of a system response deemed to warrant further investigation by the demonstrator for consideration as an emplaced munitions item.

Detection: An anomaly location that is within R_{halo} of an emplaced munitions item.

Military Munitions (MM): Specific categories of MM that may pose unique explosive safety risks, including UXO as defined in 10 USC 101(e)(5), DMM as defined in 10 USC 2710(e)(2) and/or munitions constituents (e.g., TNT, RDX) as defined in 10 USC 2710(e)(3) that are present in high enough concentrations to pose an explosive hazard.

Emplaced Munitions: A munitions item buried by the government at a specified location in the test site.

Emplaced Clutter: A clutter item (i.e., nonmunitions item) buried by the government at a specified location in the test site.

R_{halo}: A predetermined radius about an emplaced item (clutter or munitions) within which an anomaly identified by the demonstrator as being of interest is considered to be a detection of that item. For the purpose of this program, a circular halo 0.5 meters in radius is placed around the center of the object for all clutter and munitions items.

Small Munitions: Caliber of munitions less than or equal to 40 mm (includes 20-mm projectile, 25-mm projectile, 37-mm projectile, 40-mm projectile, submunitions BLU-26, BLU-63, and M42).

Medium Munitions: Caliber of munitions greater than 40 mm and less than or equal to 81 mm (includes 57-mm projectile, 60-mm mortar, 2.75-inch rocket, and 81-mm mortar).

Large Munitions: Caliber of munitions greater than 81 mm (includes 105-mm HEAT, 105-mm projectile, and 155-mm projectile).

Group: Two or more adjacent GT items with overlapping halos.

GT: Ground truth

Response Stage Noise Level: The level that represents the signal level below which anomalies are not considered detectable. Demonstrators are required to provide the recommended noise level for the blind grid test area.

Discrimination Stage Threshold: The demonstrator-selected threshold level that is expected to provide optimum performance of the system by retaining all detectable munitions and rejecting the maximum amount of clutter. This level defines the subset of anomalies the demonstrator would recommend digging based on discrimination.

Binomially Distributed Random Variable: A random variable of the type which has only two possible outcomes, say success and failure, is repeated for *n* independent trials with the probability *p* of success and the probability *1-p* of failure being the same for each trial. The number of successes *x* observed in the *n* trials is an estimate of *p* and is considered to be a binomially distributed random variable.

RESPONSE AND DISCRIMINATION STAGE DATA

The scoring of the demonstrator's performance is conducted in two stages: response stage and discrimination stage. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver-operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of clutter detection (P_{cd}) or probability of false positive (P_{fp}). Those that do not correspond to any known item are termed background alarms.

The response stage is a measure of whether the sensor can detect an object of interest. For a channel instrument, this value should be closely related to the amplitude of the signal. The demonstrator must report the response level (threshold) below which target responses are deemed insufficient to warrant further investigation. At this stage, minimal processing may be done. This includes filtering long- and short-scale variations, bias removal, and scaling. This processing should be detailed in the data submission.

For a multichannel instrument, the demonstrator must construct a quantity analogous to amplitude. The demonstrator should consider what combination of channels provides the best test for detecting any object that the sensor can detect. The average amplitude across a set of channels is an example of an acceptable response stage quantity. Other methods may be more appropriate for a given sensor. Again, minimal processing can be done, and the demonstrator should explain how this quantity was constructed in their data submission.

The discrimination stage evaluates the demonstrator's ability to correctly identify munitions as such, and to reject clutter. For the same locations as in the response stage anomaly list, the discrimination stage list contains the output of the algorithms applied in the discrimination-stage processing. This list is prioritized based on the demonstrator's determination that an anomaly location is likely to contain munitions. Thus, higher output values are indicative of higher confidence that a munitions item is present at the specified location. For electronic signal processing, priority ranking is based on algorithm output. For other systems, priority ranking is based on human judgment. The demonstrator also selects the threshold that the demonstrator believes will provide optimum system performance, (i.e., that retains all the detected munitions and rejects the maximum amount of clutter).

Note: The two lists provided by the demonstrator contain identical numbers of potential target locations. They differ only in the priority ranking of the declarations.

GROUP SCORING FACTORS

Based on configuration of the GT at the standardized sites and the defined scoring methodology, there exists munitions groups defined as having overlapping halos. In these cases, the following scoring logic is implemented (fig. A-1 through A-9):

a. Overall site scores (i.e., P_d) will consider only isolated munitions and clutter items.

b. GT items that have overlapping halos (both munitions and clutter) will form a group and groups may form chains.

c. Groups will have a complex halos composed of all the composite halos of all its GT items.

d. Groups will have three scoring factors: groups found groups identified and group coverage. Scores will be based on 1:1 matches of anomalies and GT.

(1) Groups Found (Found): the number of groups that have one or more GT items matched divided by the total number of groups. Demonstrators will be credited with detecting a group if any item within the group is matched to an anomaly in their list.

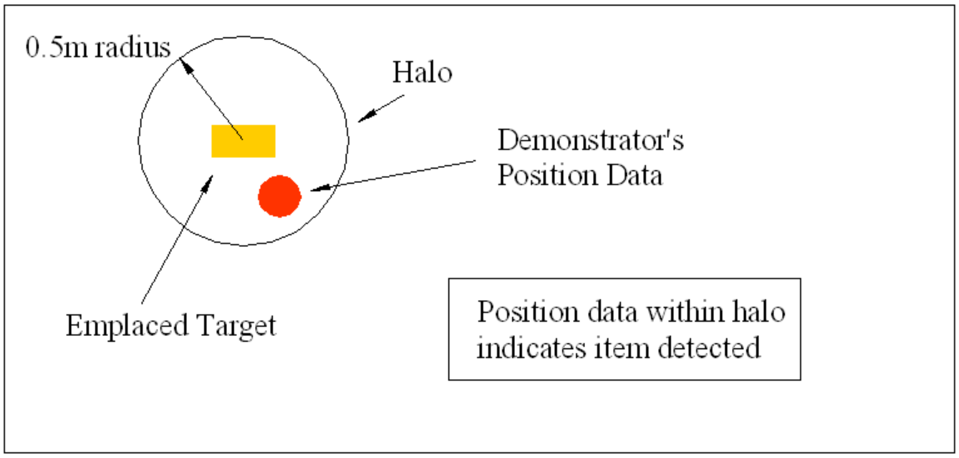
(2) Groups Identified (ID): the number of groups that have two or more GT items matched divided by the total number of groups. Demonstrators will be credited with identifying that a group is present if multiple items within the composite halo are matched to anomalies in their list.

(3) Group Coverage (Coverage): the number of GT items matched within groups divided by the total number of GT items within groups. This metric measures the demonstrator accuracy in determining the number of anomalies within a group. If five items are present and only two anomalies are matched, the demonstrator will score 0.4. If all five are matched the demonstrator will score 1.0.

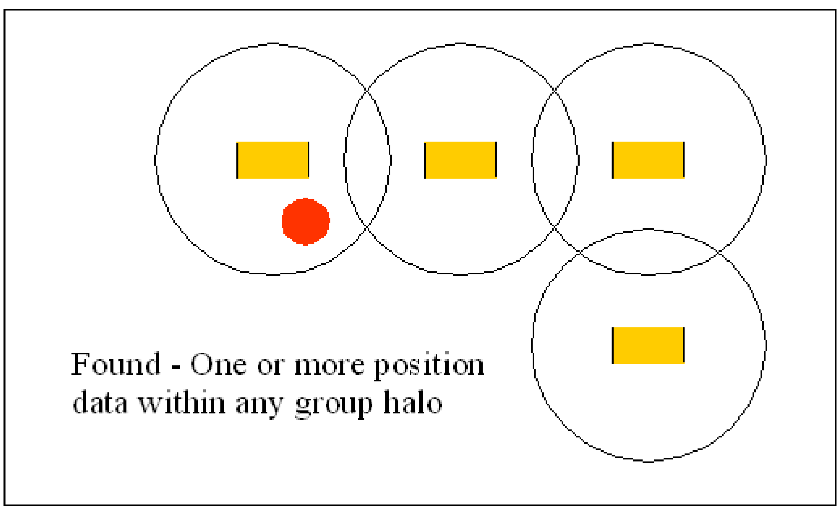
e. Location error will not be reported for groups.

f. Demonstrators will not be asked to call out groups in their scoring submissions. If multiple anomalies are indicated in a small area, the demonstrator will report all individual anomalies.

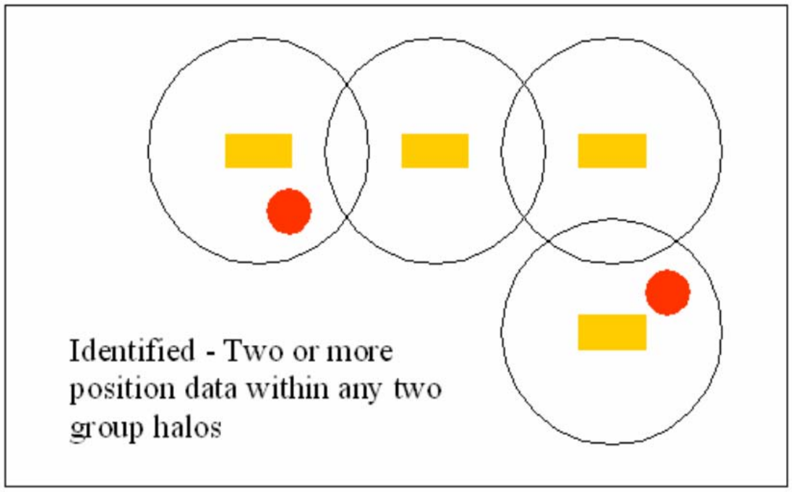
g. Excess alarms within a halo will be disregarded.



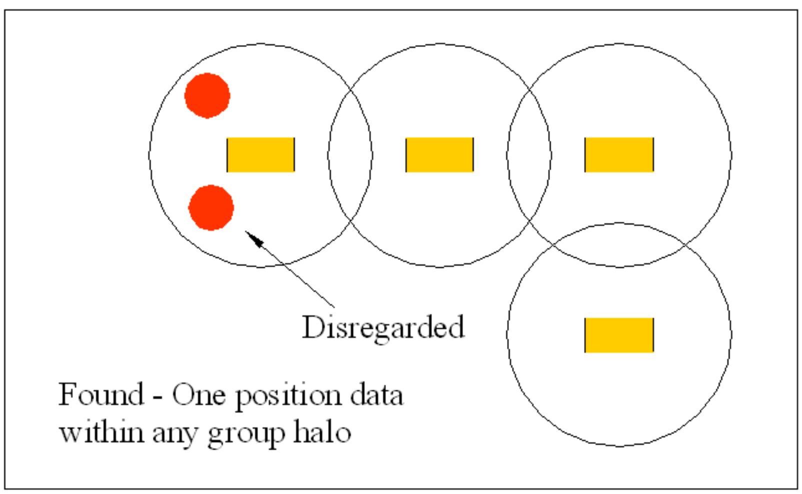
A-1. Example of detected item.



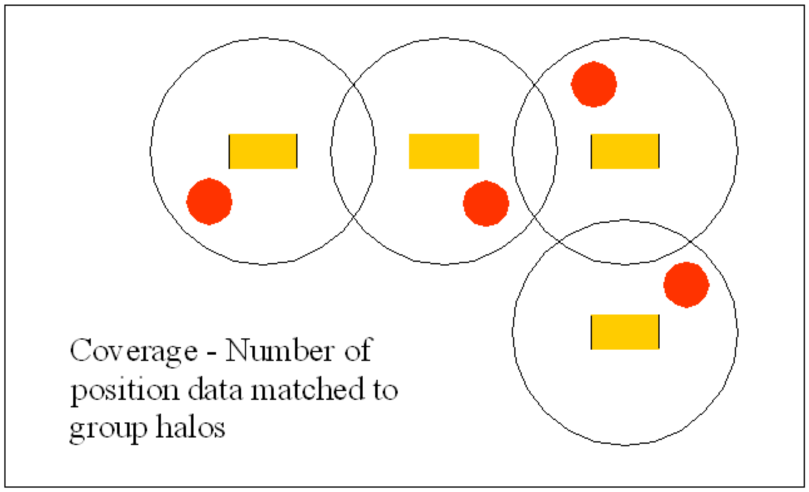
A-2. Example of group found (found).



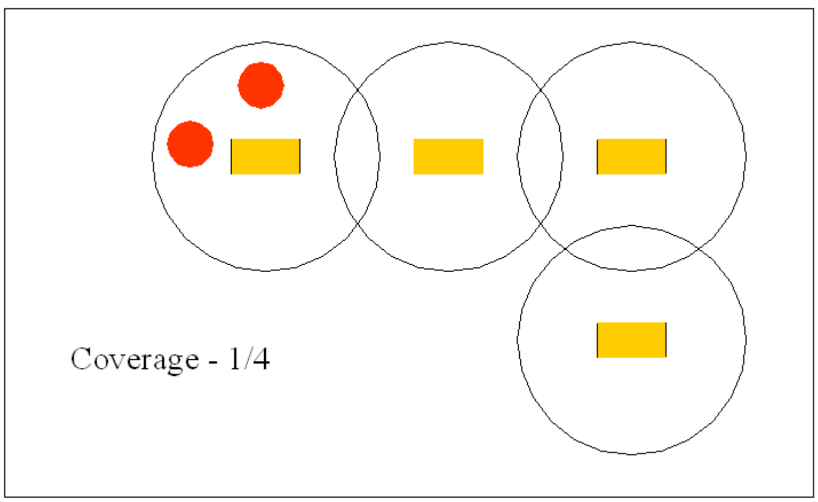
A-3. Example of group identified (ID).



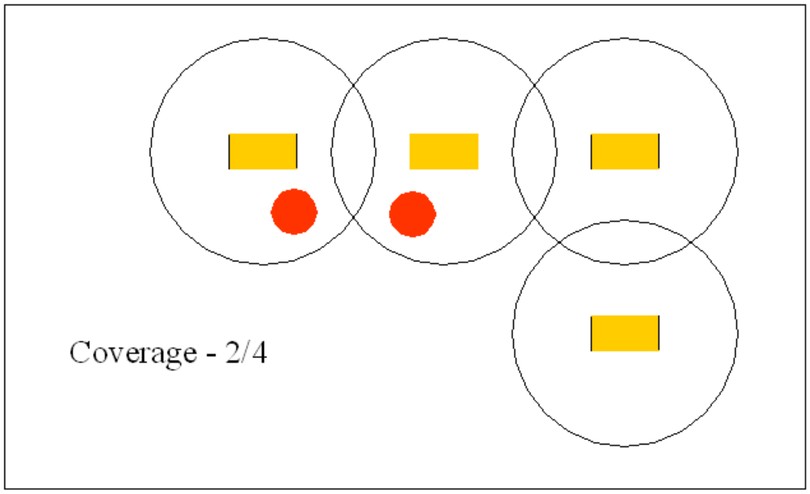
A-4. Example of excess alarms disregarded.



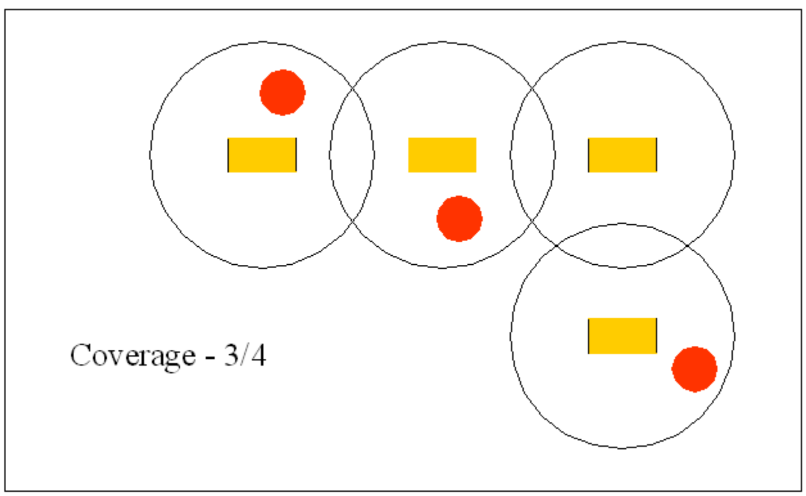
A-5. Example of a group.



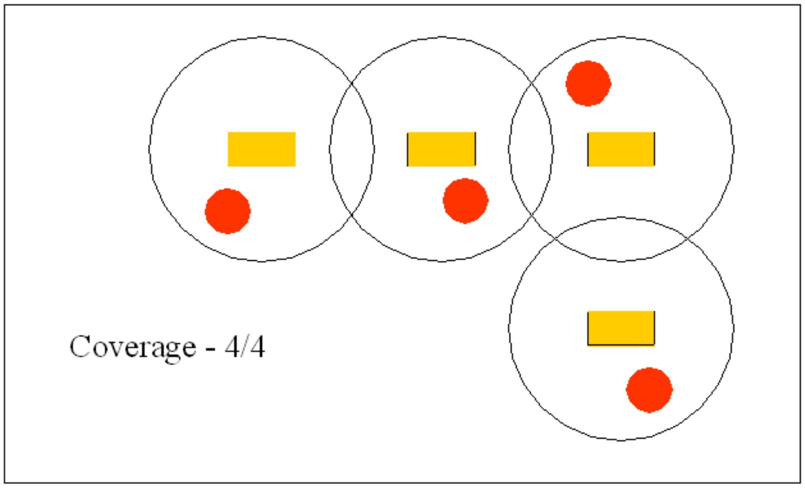
A-6. Example of group (1/4 = 0.25).



A-7. Example of group (2/4 = 0.5).



A-8. Example of group (3/4 = 0.75).



A-9. Example of group (4/4 = 1.0).

RESPONSE STAGE DEFINITIONS

Response Stage Probability of Detection (P_d^{res}): P_d^{res} = (No. of response-stage detections)/(No. of emplaced munitions in the test site).

Response Stage Clutter Detection (cd^{res}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Response Stage Probability of Clutter Detection (P_{cd}^{res}): P_{cd}^{res} = (No. of response-stage clutter detections)/(No. of emplaced clutter items).

Response Stage Background Alarm (ba^{res}): An anomaly in a blind grid cell that contains neither emplaced munitions nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced munitions or emplaced clutter item.

Response Stage Probability of Background Alarm (P_{ba}^{res}): Blind grid only: P_{ba}^{res} = (No. of response-stage background alarms)/(No. of empty grid locations).

Response Stage Background Alarm Rate (BAR^{res}): Open field any challenge area (including the direct and indirect firing sub areas) only: BAR^{res} = (No. of response-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{res}, P_{cd}^{res}, P_{ba}^{res}, and BAR^{res} are functions of t^{res}, the threshold applied to the response-stage signal strength. These quantities can therefore be written as $P_d^{res}(t^{res})$, $P_{cd}^{res}(t^{res})$, $P_{ba}^{res}(t^{res})$, and $BAR^{res}(t^{res})$.

DISCRIMINATION STAGE DEFINITIONS

Discrimination: The application of a signal processing algorithm or human judgment to sensor data to discriminate munitions from clutter. Discrimination should identify anomalies that the demonstrator has high confidence correspond to munitions, as well as those that the demonstrator has high confidence correspond to nonmunitions or background returns. The former should be ranked with highest priority and the latter with lowest.

Discrimination Stage Probability of Detection (P_d^{disc}): P_d^{disc} = (No. of discrimination-stage detections)/(No. of emplaced munitions in the test site).

Discrimination Stage False Positive (fp^{disc}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Discrimination Stage Probability of False Positive (P_{fp}^{disc}): P_{fp}^{disc} = (No. of discrimination stage false positives)/(No. of emplaced clutter items).

Discrimination Stage Background Alarm (ba^{disc}): An anomaly in a blind grid cell that contains neither emplaced munitions nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced munitions or emplaced clutter item.

Discrimination Stage Probability of Background Alarm (P_{ba}^{disc}): P_{ba}^{disc} = (No. of discrimination-stage background alarms)/(No. of empty grid locations).

Discrimination Stage Background Alarm Rate (BAR^{disc}): BAR^{disc} = (No. of discrimination-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{disc}, P_{fp}^{disc}, P_{ba}^{disc}, and BAR^{disc} are functions of t^{disc}, the threshold applied to the discrimination-stage signal strength. These quantities can therefore be written as $P_d^{disc}(t^{disc})$, $P_{fp}^{disc}(t^{disc})$, $P_{ba}^{disc}(t^{disc})$, and $BAR^{disc}(t^{disc})$.

RECEIVER-OPERATING CHARACTERISTIC (ROC) CURVES

ROC curves at both the response and discrimination stages can be constructed based on the above definitions. The ROC curves plot the relationship between P_d versus P_{cd} or P_{fp} and P_d versus BAR or P_{ba} as the threshold applied to the signal strength is varied from its minimum (t_{min}) to its maximum (t_{max}) value.[1] P_d versus P_{fp} and P_d versus BAR being combined into ROC curves are shown in Figure A-10. Note that the "res" and "disc" superscripts have been suppressed from all the variables for clarity.

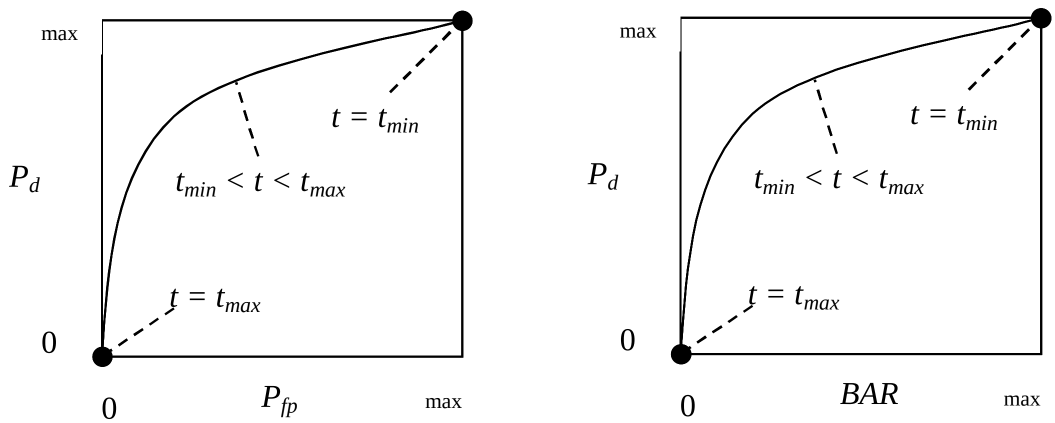


Figure A-10. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

METRICS TO CHARACTERIZE THE DISCRIMINATION STAGE

The demonstrator is also scored on efficiency and rejection ratio, which measure the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of munitions detections from the anomaly list while rejecting the maximum number of anomalies arising from nonmunitions items. The efficiency measures the fraction of detected munitions retained by the discrimination, while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the entire response list, i.e., the maximum munitions detectable by the sensor and its accompanying clutter detection rate/false positive rate or background alarm rate.

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[1]Strictly speaking, ROC curves plot the P_d versus P_{ba} over a predetermined and fixed number of detection opportunities (some of the opportunities are located over munitions and others are located over clutter or blank spots). In an open field scenario, each system suppresses its signal strength reports until some bare-minimum signal response is received by the system. Consequently, the open field ROC curves do not have information from low signal-output locations, and, furthermore, different contractors report their signals over a different set of locations on the ground. These ROC curves are thus not true to the strict definition of ROC curves as defined in textbooks on detection theory. Note, however, that the ROC curves obtained in the blind grid test sites are true ROC curves.

Efficiency (E): $E = P_d^{disc}(t^{disc})/P_d^{res}(t_{min}^{res})$: Measures (at a threshold of interest) the degree to which the maximum theoretical detection performance of the sensor system (as determined by the response stage tmin) is preserved after application of discrimination techniques. Efficiency is a number between 0 and 1. An efficiency of 1 implies that all of the munitions initially detected in the response stage were retained at the specified threshold in the discrimination stage, t^{disc}.

False Positive Rejection Rate (R_{fp}): $R_{fp} = 1 - [P_{fp}^{disc}(t^{disc})/P_{cd}^{res}(t_{min}^{res})]$: Measures (at a threshold of interest) the degree to which the sensor system's false positive performance is improved over the maximum false positive performance (as determined by the response stage tmin). The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all emplaced clutter initially detected in the response stage were correctly rejected at the specified threshold in the discrimination stage.

Background Alarm Rejection Rate (R_{ba}):

Blind grid: $R_{ba} = 1 - [P_{ba}^{disc}(t^{disc})/P_{ba}^{res}(t_{min}^{res})]$.
Open field: $R_{ba} = 1 - [BAR^{disc}(t^{disc})/BAR^{res}(t_{min}^{res})])$.

Measures the degree to which the discrimination stage correctly rejects background alarms initially detected in the response stage. The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all background alarms initially detected in the response stage were rejected at the specified threshold in the discrimination stage.

CHI-SQUARE COMPARISON

The Chi-square test for differences in probabilities (or 2 by 2 contingency table) is used to analyze two samples drawn from two different populations to see if both populations have the same or different proportions of elements in a certain category. More specifically, two random samples are drawn, one from each population, to test the null hypothesis that the probability of event A (some specified event) is the same for both populations.

The test statistic of the 2 by 2 contingency table is the Chi-square distribution with one degree of freedom. When an association between a more challenging terrain feature and relatively degraded performance is sought, a one-sided test is performed. A two-sided 2 by 2 contingency table is used in the Standardized UXO Technology Demonstration Site Program to compare performance between any two areas or subareas when the direction of degradation cannot be predetermined.

For a one-sided test, a significance level of 0.05 is used to set the critical decision limit. It is a critical decision limit because if the test statistic calculated from the data exceeds this value, then the lower proportion tested will be considered significantly less than the greater one (degraded). If the test statistic calculated from the data is less than this value, then no degradation can be said to exist because of the terrain feature introduced.

For a two-sided test, a significance level of 0.10 is used to allow .05 on either side of the decision. It is a critical decision limit because if the test statistic calculated from the data exceeds this value, then the two proportions tested will be considered significantly different. If the test statistic calculated from the data is less than this value, then the two proportions tested will be considered not significantly different.

An exception must be applied when either a 0 or 100 percent success rate occurs in the sample data. The Chi-square test cannot be used in these instances. Instead, Fischer's test is used, and the critical decision limit for one-sided tests is the chosen significance level, which in this case is 0.05. With Fischer's test, if the test statistic is less than the critical value, then the proportions are considered to be significantly different.

An example follows that illustrates Standardized UXO Technology Demonstration Site blind grid results compared to those from the open field legacy. It should be noted that a significant result does not prove a cause-and-effect relationship exists between the two populations of interest; however, it does serve as a tool to indicate that one data set has experienced a degradation or change in system performance at a large enough level than can be accounted for merely by chance or random variation. Note also that a result that is not significant indicates that there is not enough evidence to declare that anything more than chance or random variation within the same population is at work between the two data sets being compared.

Demonstrator X achieves the following overall results after surveying the blind grid and open field (legacy) using the same system (results indicate the number of munitions detected divided by the number of munitions emplaced):

	Blind grid	Open field
P_d^{res}	100/100 = 1.0	8/10 = .80

P_d^{res}: BLIND GRID versus OPEN FIELD (legacy). Using the example data above to compare probabilities of detection in the response stage, all 100 munitions out of 100 emplaced munitions items were detected in the blind grid while 8 munitions out of 10 emplaced were detected in the open field. Fischer's test must be used since a 100 percent success rate occurs in the data. Fischer's test uses the four input values to calculate a test statistic of 0.0075 that is compared against the critical value of 0.05. Since the test statistic is less than the critical value, the smaller response stage detection rate (0.80) is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause-and-effect relationship exists between the change in survey area and degradation in performance, it does indicate that the detection ability of demonstrator X's system seems to have been degraded in the open field relative to results from the blind grid using the same system. This is an example of a one-sided Chi-squared test.

APPENDIX B. DAILY WEATHER LOGS

Date, 10	Time, [a]EST	Avg. Temp, °F	Total Precip., in.
2 Mar	0700	33.3	0.00
	0800	34.2	0.00
	0900	37.2	0.00
	1000	40.8	0.00
	1100	42.3	0.00
	1200	43.0	0.00
	1300	43.3	0.00
	1400	43.7	0.00
	1500	43.5	0.00
	1600	42.6	0.00
	1700	41.0	0.00
3 Mar	0700	37.8	0.00
	0800	38.1	0.00
	0900	38.5	0.00
	1000	39.0	0.00
	1100	39.6	0.00
	1200	40.1	0.00
	1300	41.4	0.00
	1400	41.7	0.00
	1500	42.6	0.00
	1600	42.8	0.00
	1700	43.0	0.00
4 Mar	0700	35.6	0.00
	0800	36.1	0.00
	0900	38.1	0.00
	1000	40.5	0.00
	1100	41.9	0.00
	1200	42.1	0.00
	1300	43.2	0.00
	1400	44.8	0.00
	1500	45.7	0.00
	1600	45.9	0.00
	1700	45.5	0.00

[a]Eastern Standard Time.

Date, 10	Time, [a]EST	Avg. Temp, °F	Total Precip., in.
5 Mar	0700	36.5	0.00
	0800	36.7	0.00
	0900	38.5	0.00
	1000	39.7	0.00
	1100	41.2	0.00
	1200	44.4	0.00
	1300	46.4	0.00
	1400	47.8	0.00
	1500	47.3	0.00
	1600	48.0	0.00
	1700	47.5	0.00
8 Mar	0700	35.6	0.00
	0800	39.0	0.00
	0900	44.2	0.00
	1000	49.8	0.00
	1100	52.5	0.00
	1200	54.5	0.00
	1300	56.7	0.00
	1400	58.3	0.00
	1500	59.7	0.00
	1600	60.1	0.00
	1700	59.9	0.00
9 Mar	0700	36.7	0.00
	0800	39.0	0.00
	0900	50.7	0.00
	1000	54.3	0.00
	1100	57.2	0.00
	1200	59.5	0.00
	1300	60.8	0.00
	1400	61.2	0.00
	1500	62.1	0.00
	1600	62.2	0.00
	1700	61.5	0.00

[a]Eastern Standard Time.

Date, 10	**Time, [a]EST**	**Avg. Temp, °F**	**Total Precip., in.**
10 Mar	0700	40.1	0.00
	0800	42.4	0.00
	0900	45.3	0.00
	1000	46.6	0.00
	1100	48.0	0.00
	1200	51.1	0.00
	1300	53.1	0.00
	1400	55.6	0.00
	1500	58.1	0.00
	1600	59.2	0.00
	1700	59.9	0.00

[a]Eastern Standard Time.

APPENDIX C.   SOIL MOISTURE

Date: 3 Mar 10 **Time:** NA, 1400			
Probe Location	**Layer, in.**	**A.M. Reading, %**	**P.M. Reading, %**
Wet area	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Wooded area	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Open area	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Calibration lanes	0 to 6	--	28.9
	6 to 12	--	31.7
	12 to 24	--	34.8
	24 to 36	--	39.7
	36 to 48	--	44.1
Blind grid/moguls	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--

Date: 4 Mar 10 **Time:** 0930, 1500			
Probe Location	**Layer, in.**	**A.M. Reading, %**	**P.M. Reading, %**
Wet area	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Wooded area	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Open area	0 to 6	--	31.2
	6 to 12	--	33.1
	12 to 24	--	34.8
	24 to 36	--	39.7
	36 to 48	--	41.8
Calibration lanes	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Blind grid/moguls	0 to 6	18.6	--
	6 to 12	29.3	--
	12 to 24	34.7	--
	24 to 36	38.2	--
	36 to 48	39.9	--

Date: 5 Mar 10 **Time:** 0900, 1500			
Probe Location	**Layer, in.**	**A.M. Reading, %**	**P.M. Reading, %**
Wet area	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Wooded area	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Open area	0 to 6	31.0	30.9
	6 to 12	32.8	32.8
	12 to 24	34.6	34.4
	24 to 36	39.8	39.7
	36 to 48	41.9	41.7
Calibration lanes	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Blind grid/moguls	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--

Date: 8 Mar 10 **Time:** 0800, 1400			
Probe Location	**Layer, in.**	**A.M. Reading, %**	**P.M. Reading, %**
Wet area	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Wooded area	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Open area	0 to 6	30.5	30.4
	6 to 12	32.4	32.5
	12 to 24	34.2	34.2
	24 to 36	39.4	39.2
	36 to 48	41.8	41.9
Calibration lanes	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Blind grid/moguls	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--

Date: 9 Mar 10
Time: 0900, 1500

Probe Location	Layer, in.	A.M. Reading, %	P.M. Reading, %
Wet area	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Wooded area	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Open area	0 to 6	30.1	30.0
	6 to 12	32.3	32.2
	12 to 24	33.9	33.9
	24 to 36	38.8	38.6
	36 to 48	41.6	41.4
Calibration lanes	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Blind grid/moguls	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--

Date: 10 Mar 10
Time: 0830, 1500

Probe Location	Layer, in.	A.M. Reading, %	P.M. Reading, %
Wet area	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Wooded area	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Open area	0 to 6	29.7	29.6
	6 to 12	32.0	31.7
	12 to 24	33.4	33.5
	24 to 36	38.2	38.2
	36 to 48	41.2	41.0
Calibration lanes	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--
Blind grid/moguls	0 to 6	--	--
	6 to 12	--	--
	12 to 24	--	--
	24 to 36	--	--
	36 to 48	--	--

APPENDIX D. DAILY ACTIVITY LOGS

Date	No. of People	AreaTested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions	
3/2/2010	3	CALIBRATION LANES	1445	1600	75	INITIAL SET-UP	INITIAL SET UP	GPS	LINEAR	RAINY	MUDDY
3/3/2010	3	CALIBRATION LANES	730	1155	265	INITIAL SET-UP	INITIAL SET UP	GPS	LINEAR	RAINY	MUDDY
3/3/2010	3	CALIBRATION LANES	1155	1425	150	COLLECTING DATA	COLLECT DATA	GPS	LINEAR	RAINY	MUDDY
3/3/2010	3	CALIBRATION LANES	1425	1440	15	CALIBRATION	CALIBRATE	GPS	LINEAR	RAINY	MUDDY
3/3/2010	3	CALIBRATION LANES	1440	1500	20	DOWNTIME DUE TO EQUIP MAINT/CHECK	DOWNLOAD DATA	GPS	LINEAR	RAINY	MUDDY
3/3/2010	3	CALIBRATION LANES	1500	1515	15	BREAK/LUNCH	BREAK/LUNCH	GPS	LINEAR	RAINY	MUDDY
3/3/2010	3	CALIBRATION LANES	1515	1540	25	DOWNTIME DUE TO EQUIP MAINT/CHECK	DATA CHECK	GPS	LINEAR	RAINY	MUDDY
3/3/2010	3	CALIBRATION LANES	1540	1600	20	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	LINEAR	RAINY	MUDDY
3/4/2010	3	BLIND TEST GRID	740	825	45	DAILY START, STOP	SET UP EQUIPMENT	GPS	LINEAR	SUNNY	MUDDY
3/4/2010	3	BLIND TEST GRID	825	845	20	CALIBRATION	CALIBRATE	GPS	LINEAR	SUNNY	MUDDY
3/4/2010	3	BLIND TEST GRID	845	1235	230	COLLECTING DATA	COLLECT DATA	GPS	LINEAR	SUNNY	MUDDY
3/4/2010	3	BLIND TEST GRID	1235	1300	25	CALIBRATION	CALIBRATE	GPS	LINEAR	SUNNY	MUDDY
3/4/2010	3	BLIND TEST GRID	1300	1335	35	BREAK/LUNCH	BREAK/LUNCH	GPS	LINEAR	SUNNY	MUDDY
3/4/2010	3	OPEN FIELD	1335	1450	75	DAILY START, STOP	SET UP EQUIPMENT	GPS	LINEAR	SUNNY	MUDDY
3/4/2010	3	OPEN FIELD	1450	1615	85	COLLECTING DATA	COLLECT DATA, INDIRECT FIRE	GPS	LINEAR	SUNNY	MUDDY
3/4/2010	3	OPEN FIELD	1615	1635	20	CALIBRATION	CALIBRATE	GPS	LINEAR	SUNNY	MUDDY
3/4/2010	3	OPEN FIELD	1635	1700	25	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	LINEAR	SUNNY	MUDDY
3/5/2010	3	OPEN FIELD	735	905	90	DAILY START, STOP	SET UP EQUIPMENT	GPS	LINEAR	SUNNY	MUDDY
3/5/2010	3	OPEN FIELD	905	920	15	CALIBRATION	CALIBRATE	GPS	LINEAR	SUNNY	MUDDY
3/5/2010	3	OPEN FIELD	920	1020	60	DOWNTIME DUE TO EQUIPMENT FAILURE	FALUTY GPS CABLE, SODERED	GPS	LINEAR	SUNNY	MUDDY
3/5/2010	3	OPEN FIELD	1020	1030	10	CALIBRATION	CALIBRATE	GPS	LINEAR	SUNNY	MUDDY
3/5/2010	3	OPEN FIELD	1030	1200	90	COLLECTING DATA	COLLECT DATA, INDIRECT FIRE	GPS	LINEAR	SUNNY	MUDDY

Date	No. of People	AreaTested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions	
3/5/2010	3	OPEN FIELD	1200	1215	15	DAILY START, STOP	SET UP EQUIPMENT	GPS	LINEAR	SUNNY	MUDDY
3/5/2010	3	OPEN FIELD	1215	1225	10	BREAK/LUNCH	BREAK/LUNCH	GPS	LINEAR	SUNNY	MUDDY
3/5/2010	3	OPEN FIELD	1225	1520	175	COLLECTING DATA	COLLECT DATA, INDIRECT FIRE	GPS	LINEAR	SUNNY	MUDDY
3/5/2010	3	OPEN FIELD	1520	1530	10	CALIBRATION	CALIBRATE	GPS	LINEAR	SUNNY	MUDDY
3/5/2010	3	OPEN FIELD	1530	1600	30	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	LINEAR	SUNNY	MUDDY
3/8/2010	3	OPEN FIELD	735	800	25	DAILY START, STOP	SET UP EQUIPMENT	GPS	LINEAR	SUNNY	MUDDY
3/8/2010	3	OPEN FIELD	800	830	30	CALIBRATION	CALIBRATE	GPS	LINEAR	SUNNY	MUDDY
3/8/2010	3	OPEN FIELD	830	1055	145	COLLECTING DATA	COLLECT DATA, INDIRECT FIRE	GPS	LINEAR	SUNNY	MUDDY
3/8/2010	3	OPEN FIELD	1055	1125	30	DOWNTIME DUE TO EQUIPMENT FAILURE	FLAT TIRE, FIXED	GPS	LINEAR	SUNNY	MUDDY
3/8/2010	3	OPEN FIELD	1125	1530	245	COLLECTING DATA	COLLECT DATA, INDIRECT FIRE	GPS	LINEAR	SUNNY	MUDDY
3/8/2010	3	OPEN FIELD	1530	1540	10	DOWNTIME DUE TO EQUIPMENT FAILURE	FLAT TIRE, FIXED	GPS	LINEAR	SUNNY	MUDDY
3/8/2010	3	OPEN FIELD	1540	1625	45	COLLECTING DATA	COLLECT DATA, INDIRECT FIRE	GPS	LINEAR	SUNNY	MUDDY
3/8/2010	3	OPEN FIELD	1625	1635	10	CALIBRATION	CALIBRATE	GPS	LINEAR	SUNNY	MUDDY
3/8/2010	3	OPEN FIELD	1635	1700	25	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	LINEAR	SUNNY	MUDDY
3/9/2010	3	OPEN FIELD	735	805	30	DAILY START, STOP	SET UP EQUIPMENT	GPS	LINEAR	SUNNY	MUDDY
3/9/2010	3	OPEN FIELD	805	835	30	CALIBRATION	CALIBRATE	GPS	LINEAR	SUNNY	MUDDY
3/9/2010	3	OPEN FIELD	835	1115	160	COLLECTING DATA	COLLECT DATA, INDIRECT FIRE	GPS	LINEAR	SUNNY	MUDDY
3/9/2010	3	OPEN FIELD	1115	1135	20	DAILY START, STOP	SET UP EQUIPMENT	GPS	LINEAR	SUNNY	MUDDY
3/9/2010	3	OPEN FIELD	1135	1155	20	BREAK/LUNCH	BREAK/LUNCH	GPS	LINEAR	SUNNY	MUDDY
3/9/2010	3	OPEN FIELD	1155	1550	235	COLLECTING DATA	COLLECT DATA, DIRECT FIRE	GPS	LINEAR	SUNNY	MUDDY
3/9/2010	3	OPEN FIELD	1550	1555	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHANGE BATTERIES	GPS	LINEAR	SUNNY	MUDDY
3/9/2010	3	OPEN FIELD	1555	1630	35	COLLECTING DATA	COLLECT DATA, DIRECT FIRE	GPS	LINEAR	SUNNY	MUDDY

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration min.	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions	
3/9/2010	3	OPEN FIELD	1630	1640	10	CALIBRATION	CALIBRATE	GPS	LINEAR	SUNNY	MUDDY
3/9/2010	3	OPEN FIELD	1640	1700	20	DAILY START, STOP	EQUIPMENT BREAKDOWN	GPS	LINEAR	SUNNY	MUDDY
3/10/2010	3	OPEN FIELD	740	800	20	DAILY START, STOP	SET UP EQUIPMENT	GPS	LINEAR	SUNNY	MUDDY
3/10/2010	3	OPEN FIELD	800	835	35	CALIBRATION	CALIBRATE	GPS	LINEAR	SUNNY	MUDDY
3/10/2010	3	OPEN FIELD	835	1205	210	COLLECTING DATA	COLLECT DATA, DIRECT FIRE	GPS	LINEAR	SUNNY	MUDDY
3/10/2010	3	OPEN FIELD	1205	1220	15	COLLECTING DATA	COLLECT DATA, INDIRECT FIRE	GPS	LINEAR	SUNNY	MUDDY
3/10/2010	3	OPEN FIELD	1220	1235	15	CALIBRATION	CALIBRATE	GPS	LINEAR	SUNNY	MUDDY
3/10/2010	3	OPEN FIELD	1235	1320	45	DOWNTIME DUE TO EQUIP MAINT/CHECK	DOWNLOAD DATA	GPS	LINEAR	SUNNY	MUDDY
3/10/2010	3	OPEN FIELD	1320	1630	190	DEMOBILIZATION	DEMOBILIZATION	GPS	LINEAR	SUNNY	MUDDY

APPENDIX E. REFERENCES

1. Standardized UXO Technology Demonstration Site Handbook, DTC Project No. 8-CO-160-000-473, Report No. ATC-8349, March 2002.

2. Aberdeen Proving Ground Soil Survey Report, October 1998.

3. Data Summary, UXO Standardized Test Site: APG Soils Description, May 2002.

APPENDIX F. ABBREVIATIONS

APG	=	Aberdeen Proving Ground
ATC	=	U.S. Army Aberdeen Test Center
ATSS	=	Aberdeen Test Support Services
BAR	=	background alarm rate
DMM	=	discarded military munitions
EMI	=	electromagnetic interference
EQT	=	Environmental Quality Technology
ERDC	=	U.S. Army Corps of Engineers Engineering Research and Development Center
EST	=	Eastern Standard Time
ESTCP	=	Environmental Security Technology Certification Program
GPS	=	Global Positioning System
GT	=	ground truth
HDSD	=	Homeland Defense and Sustainment Division
HEAT	=	high-explosive antitank
JPG	=	Jefferson Proving Ground
MM	=	military munitions
NS	=	nonstandard munition
POC	=	point of contact
QA	=	quality assurance
QC	=	quality control
ROC	=	receiver-operating characteristic
S	=	standard munition
SAIC	=	Science Applications International Corporation
SCEMP	=	Simplified Combined EMI Magnetometer Prototype
SERDP	=	Strategic Environmental Research and Development Program
USAEC	=	U.S. Army Environmental Command
UXO	=	unexploded ordnance
YPG	=	U.S. Army Yuma Proving Ground

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